US Army Corps of Engineers ®
Wilmington District

General Re-evaluation Report and Environmental Assessment Surf City, Onslow and Pender Counties, North Carolina Coastal Storm Risk Management Project

Appendix C: Previous Geotechnical Analysis

Final

February 2025

Document 1:

West Onslow Beach and New River Inlet (Topsail Beach), NC Coastal Storm Damage Reduction: Geotechnical Appendix

1.0 Introduction

In 2010 the study of the borrow sites for the Preconstruction Engineering and Design (PED) phase of the West Onslow Beach and New River Inlet (Topsail Beach), NC Coastal Storm Damage Reduction (CSDR) Project was initiated. This project is an authorized shore protection project for the town of Topsail Beach, which is the southernmost town on Topsail Island, on the southeastern North Carolina coast. The primary purpose of the PED phase for this project is to evaluate the borrow area identified as Borrow site A (defined by USACE) and to develop the design documentation for the most suitable plan of protection for the present and near future conditions at Topsail Beach. The products from the PED phase will be used to further this project towards the construction of a berm and dune (with terminal transitions) along approximately 5.0 miles of the oceanfront in Topsail Beach.

2.0 Previous Subsurface Investigations

An initial subsurface investigation was performed between May and November 2003 for the West Onslow Beach and New River Inlet (Topsail Beach), NC CDSR Project as well as the Surf City and North Topsail Beach, NC CDSR Project, located adjacent to and approximately 10 miles to the northeast of Topsail Beach. This subsurface investigation included boring locations between 1 and 6.5 miles from the beach, water depths greater than 30 feet, and change in seismic profile, which could represent differing soil types. A total of 358 borings were performed in the Topsail Island area, 167 of which were for the Topsail Beach project. The borings were performed offshore of Topsail Beach in Banks Channel behind the town of Topsail Beach, in the connecting channel between the Atlantic Intracoastal Water Way (AIWW) and New Topsail Inlet, and in New Topsail Inlet. A combination of data from the borings and the geophysical surveys were used to identify and define borrow sites for both the Topsail Beach project and the Surf City and North Topsail Beach project. Of the 167 completed borings only 15 are within the boundary for Borrow site A. The remaining 152 completed borings were taken around Borrow site A, except for immediately southwest of Borrow site A and between Borrow site A and the beach. Following the 2003 investigation, in addition to Borrow site A being identified, neighboring Borrow sites B, C, and D were also identified as potential sediment sources for the Topsail Beach project.

In addition to the subsurface investigation in 2003, an investigation was performed in 2006 within the identified boundary for Borrow site A. The investigation was performed by Coastal Planning and Engineering of North Carolina, Inc. (CPE) to locate and evaluate sand for the Interim (Emergency) Beach Nourishment Project for the town of Topsail Beach. CPE completed 20 borings within Borrow site A, of which 13 were defined to be in a subsection of Borrow site A referred to as Borrow site A1 (Finkle et al., 2008). In the CPE report titled “Topsail Beach, North Carolina: Marine Sand Search Investigations to Locate Sand Sources for Beach Nourishment,” CPE states that the sediment in Borrow site A1 has “a mean grain size of 0.17 millimeters, with a phi sorting of 1.11, and 7.3 percent silt”. The report later states that the sand within Borrow site A1 is generally suitable but that the silt content exceeds the limits for percent silt set by the State of North Carolina. Results from the USACE 2003 and the CPE 2006 investigations are discussed in detail in Section 5 of this report.

It was determined by the Topsail Beach Project Delivery Team (PDT) (Wilmington District, USACE) that based on the results of previous subsurface investigations, Borrow site A would be the only Borrow site evaluated as part of the PED phase for the Topsail Beach Project.

3.0 Geological Framework

3.1 Regional Geology

Onslow Bay is a modern coastal embayment of the Atlantic Coastal Plain, located between Cape Lookout and Cape Fear (Figure 1). The region is underlain by a seaward thickening wedge of sedimentary rock and unconsolidated sediment, Late Cretaceous (200 Ma1[1]) to Holocene (12,000 years) age, which extends from the Fall Line to the modern continental shelf break, located 186 miles offshore (Klitgord and Behrendt, 1979, Harris et al., 1979, Snyder et al., 1982). These sediments lie unconformably atop crystalline Piedmont-affinity continental crust and rift basin complexes that were associated with Mesozoic opening of the Atlantic Ocean basin (Harris et al., 1979) that occurred 180 to 200 Ma. The sediment and rock types found in Onslow Bay and surrounding Coastal Plain owe their present distribution to a complex depositional history involving deep crustal warping (Harris et al., 1979, Harris and Zullo, 1979, Harris, 1997, Prowell and Obermeier, 1991), episodic sea-level fluctuation (Snyder et al., 1982, Snyder et al., 1991) and modern near shore processes (Thieler, 1996).

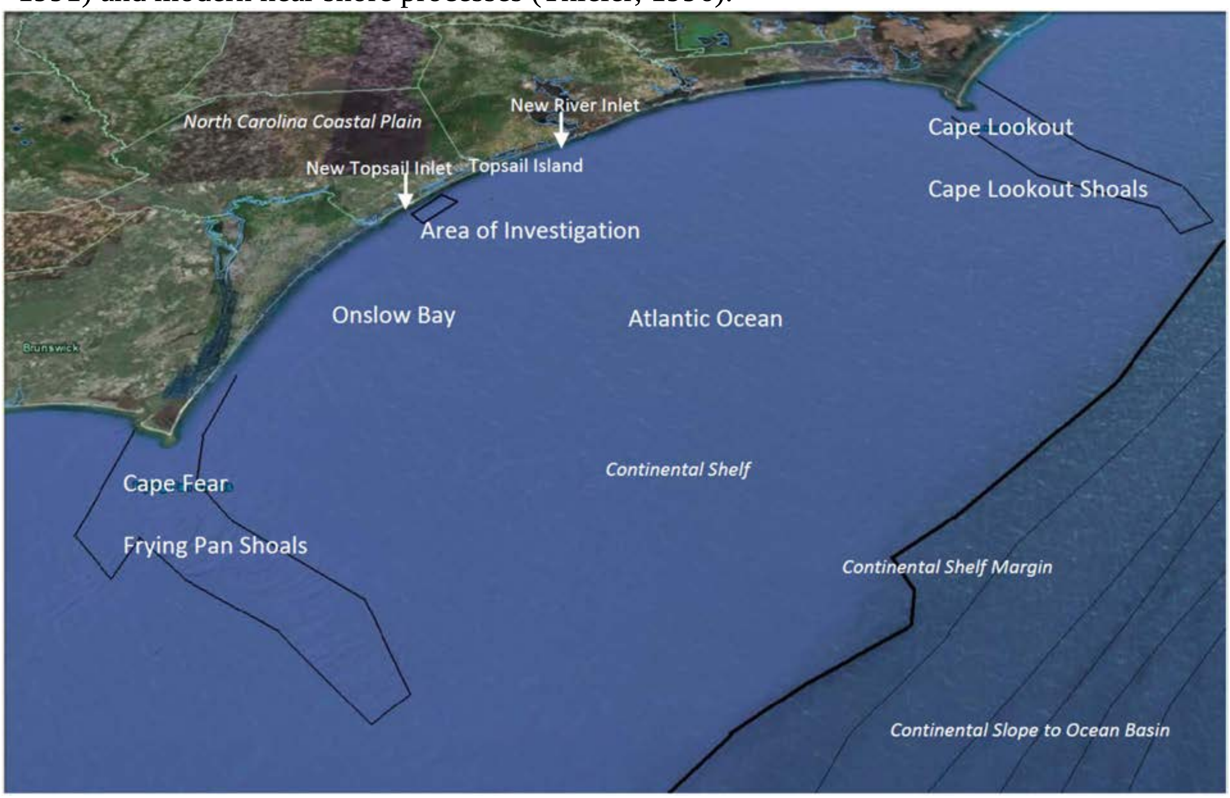

Figure 1. Major geographic features and setting of investigation area (modified from Google Earth).

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[1] Ma = Megaannum, which is a geologic unit of measure equal to one million years.

3.2 Structure

Onslow Bay lies atop crystalline continental basement rock of the Carolina Platform (Figure 2A); a pre-Jurassic-age (> 200 Ma) crustal block that partly comprises the North American continental margin (Klitgord and Behrendt, 1979, Hutchinson et al., 1982). Four major faults are rooted in this within this crustal block (Figure 2B); the Carolina Fault, Cape Fear Fault, Neuse Fault, and Graingers Wrench Zone (Harris et al., 1979). The presence of northeast trending physiographic and topographic lineaments has been interpreted to represent near-surface effects of Cenozoic (65 Ma-12,000 years ago) strike-slip faulting (Brown et al., 1977). Crustal movement and uplift beginning in the Early Cretaceous (145-112 Ma) produced a platform high between the Cape Fear and Neuse Faults, constraining Cretaceous (145-70 Ma) and Paleocene (65-78 Ma) sedimentation to the basins bounding these faults (Harris et al., 1979). Syntectonic sedimentation filled the Cretaceous-age basins up to 500 feet thick (Brown et al., 1972; Harris et al., 1979) on either side of these faults (Figure 3). Dip-slip block movement north of the Neuse Fault continued to restrict Eocene (56-37 Ma) sedimentation to areas southeast of Cape Fear (Harris et al., 1979, Snyder et al., 1988). Fault movement is considered to have ceased (Harris et al., 1979, Snyder et al., 1988) by the Oligocene (34-28 Ma), allowing sedimentation to widely distribute Oligocene sediments across Onslow Bay and Long Bay (Figure 4). Reactivation of the Neuse Fault in response to regional-scale crustal warping influenced the configuration of erosional shoreline scarps (Figure 5) during Pliocene (5.3-3.6 Ma) to Pleistocene (2.6-0.126 Ma) sea-level transgressions (Zullo and Harris, 1979).

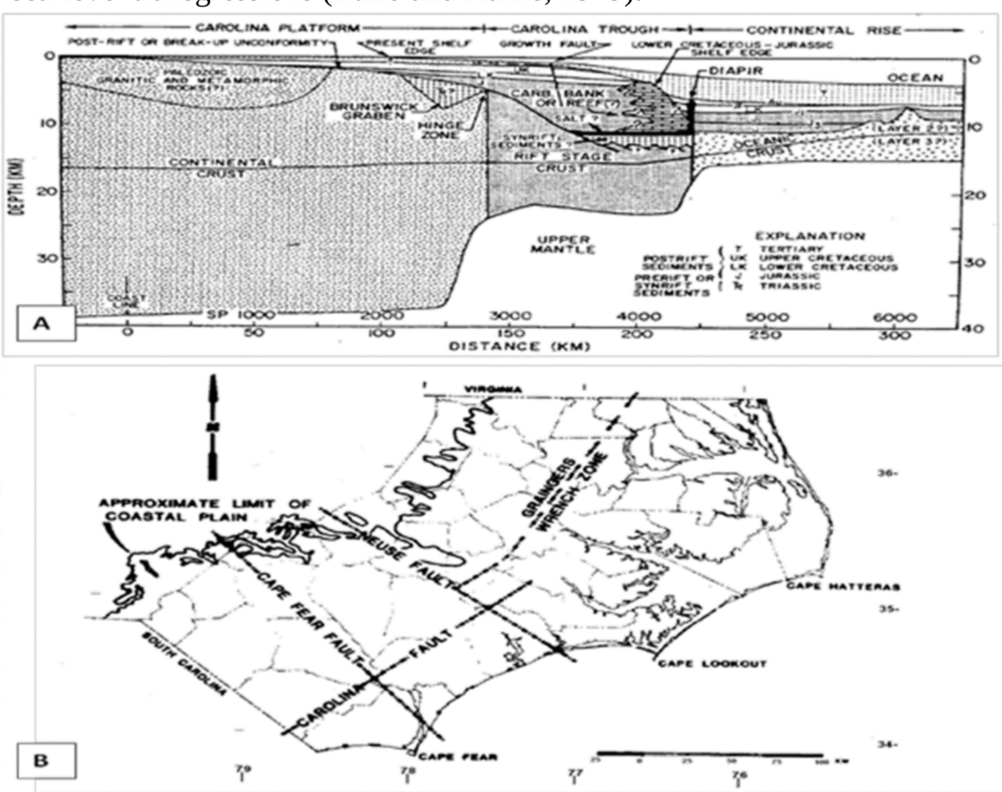


Figure 2. Basement structure of Carolina Platform and outer continental shelf. A) Crustal profile across the Carolina Platform to Atlantic Ocean basin (modified from Hutchinson et al., 1982). B) The approximate location of basement faults (modified from Harris et al., 1979).

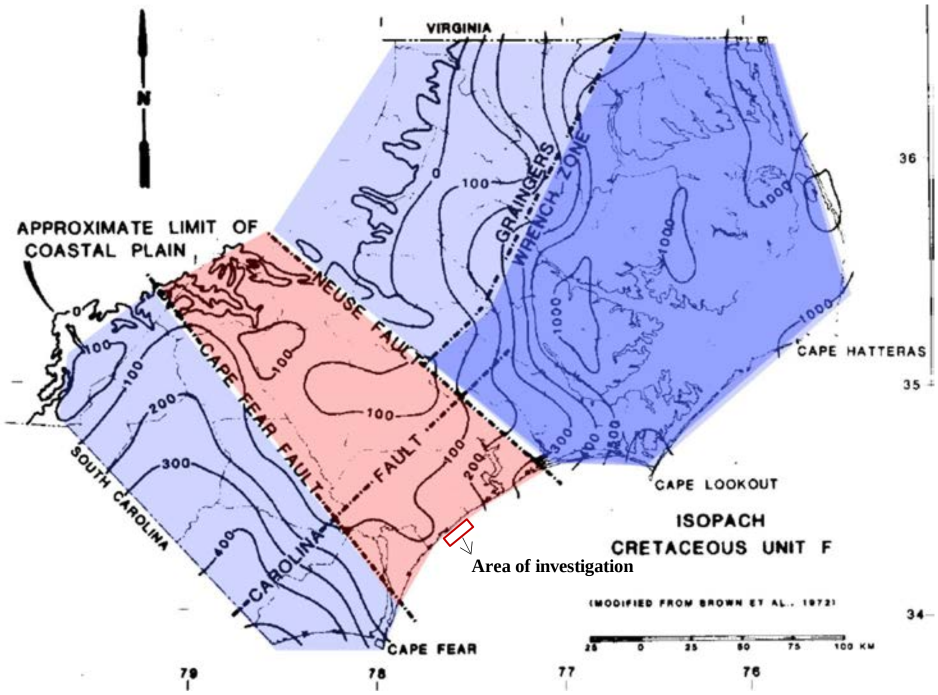


Figure 3. Basement fault control on thickness of Cretaceous-age sediment (modified from Brown et al., 1972). Note sedimentation is thinnest where faulting had uplifted crust (red). Deep Cretaceous-age basins developed on down-thrown blocks (blue and dark blue). This faulted basement configuration would continue to influence the thickness and distribution of sediments throughout the Tertiary.

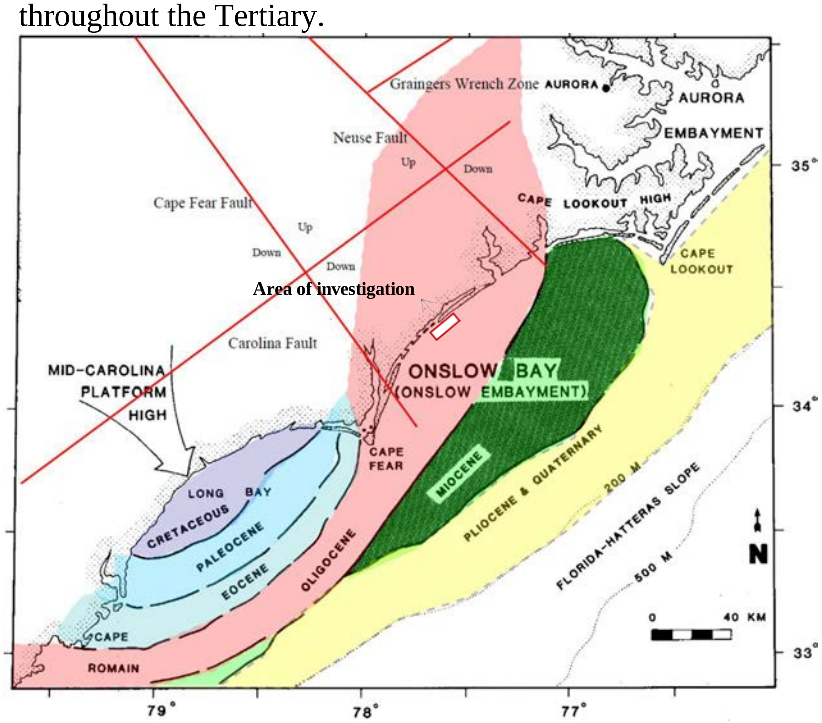


Figure 4. Structural control on distribution of Tertiary strata (modified from Snyder et al., 1988 and Harris et al., 1979). Note that progressively younger strata (lighter color) outcrop in belts farther offshore and across the continental shelf.

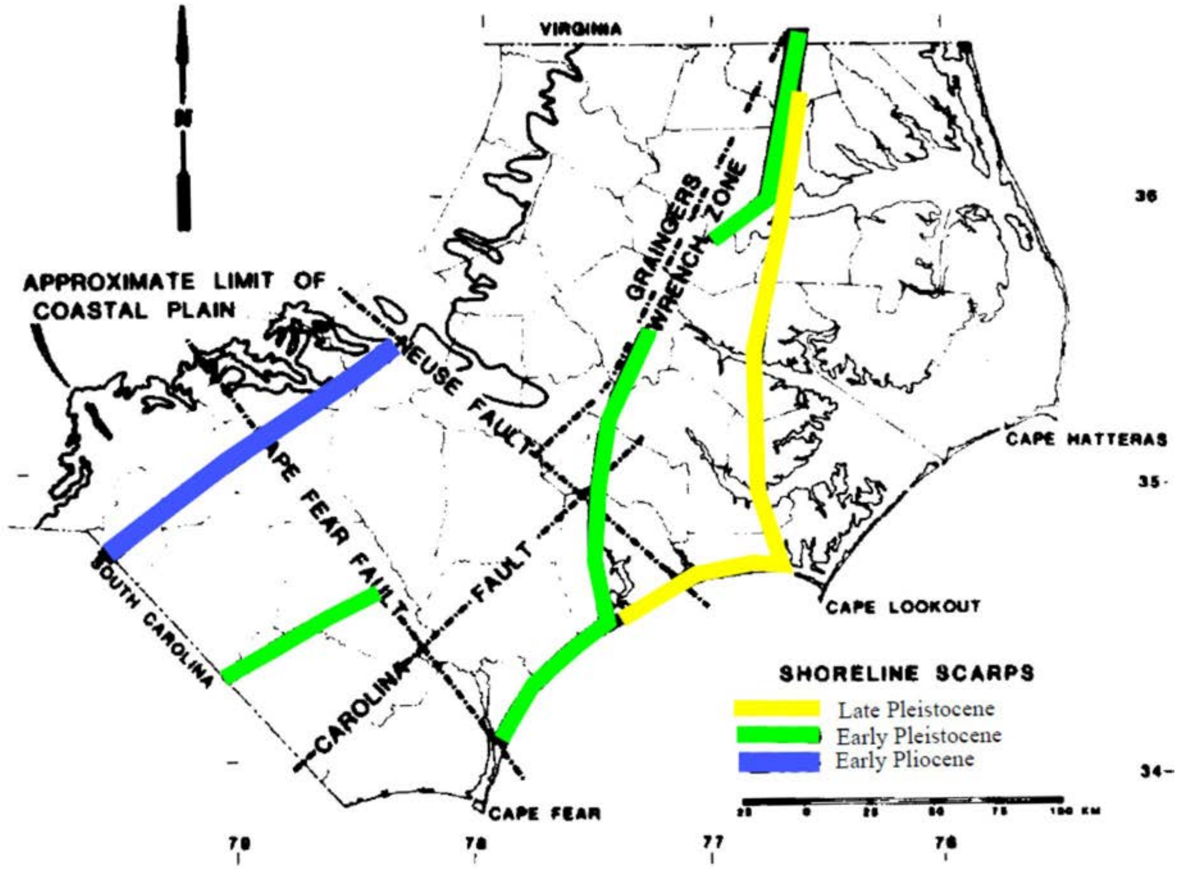


Figure 5. Basement structural control on Pliocene-Pleistocene transgressional scarp formation (modified from Zullo and Harris, 1979).

3.3 Stratigraphy

The stratigraphic record of the North Carolina coastal plain and Onslow Bay records a complex depositional history of major fluctuations in sea-level, driven by Tertiary (65-1.8 Ma) glacial cycles (Haq et al., 1987). Cretaceous-age deltaic deposits are the oldest strata within the Coastal Plain; however, these are only exposed in outcrop (Figure 6A) along the Cape Fear River and Tar River (Sohl and Owens, 1991), or within quarries (Zullo and Harris, 1987). Nine major transgressional events starting in the Eocene continuing through the Early Miocene (56-20 Ma), are recorded in strata exposed (Figure 6A and B) within quarries across southeast North Carolina (Zullo and Harris, 1987). Lithologic evidence for coastal-transgression is preserved off-shore in Onslow Bay. Within Onslow Bay and the continental shelf, sedimentary strata are comprised of unconformity-bound Oligocene to Quaternary (34-2.6 Ma) sediments that record episodic fluctuations in eustatic seal-level (Snyder, 1982, Snyder et al., 1982, Riggs et al., 1985). These sediments were originally deposited as a deltaic accretionary fan into a structurally controlled basin (Klitgord and Behrendt, 1979, Snyder, 1982, Snyder et al., 1982, Riggs et al., 1985). These strata slope seaward on average 3 feet/mile (Riggs and Ames, 2003) and thicken both southward- parallel to, and eastward-toward, the continental shelf margin (Snyder, 1982, Snyder et al., 1982, Riggs et al., 1985). The sediments were successively deposited as onlapping sequences atop older strata as the continental shelf prograded seaward toward the shelf margin throughout the Tertiary (Snyder et al., 1982, Snyder et al., 1988). Within the sedimentary fan, Oligocene and Miocene sequences are bounded by third order or higher, erosional unconformities representing periods of extreme shore face erosion in response to sea-level fluctuation (Harris and Zullo, 1991, Haq et al., 1987, Snyder, 1982, Snyder et al., 1982, Riggs et al., 1985, Snyder et al., 1991). Significant erosion removed Pliocene and younger strata (<5.3 Ma) from the stratigraphic record of Onslow Bay; with exception for a few erosional outliers, these sediments are only exposed further offshore along the shelf margin (Riggs et al., 1985, Snyder et al., 1988, Snyder et al., 1991). Incised into these strata are numerous high-relief Tertiary (65-1.8 Ma) and younger Quaternary-aged (2.6 Ma-Present) channels that extend from several hundred feet from the modern shoreface to 17 miles offshore (Hine and Snyder, 1985). Channel orientation and width varies, but many of these are considered to represent buried lower coastal plain fluvial systems (Hine and Snyder, 1985).

3.4 Stratigraphic Units

The distribution and stratigraphic relationship of strata within Onslow Bay is depicted in Figure 7. The oldest strata outcropping within Onslow Bay are Oligocene in age (OSI, 2004, Snyder et al., 1991, Snyder et al., 1988). Oligocene (34-28 Ma) strata are comprised of deltaic deposits (Snyder et al., 1982) of moldic-biomicrudites interbedded with unconsolidated calcarenite sands and grayish-green calcareous quartz sands (Riggs et al., 1985), which are correlated (Lewis et al., 1982, Snyder, 1982, Snyder, 1983) to the Trent, Belgrade and Silverdale Formations of Baum et al. (1979). A major unconformity separates the Miocene Pungo River Formation from the Oligocene sequence (Figure 7) and limits its updip position from the New River to a distance of 21 miles offshore (Riggs et al., 1985, Snyder et al., 1982, Snyder et al., 1988). The Pungo River Formation consists of interbedded carbonate sands, siliciclastic sands, and mud and phosphorite sands that grade both laterally to east (Figure 7) and south across the continental shelf (Snyder et al., 1988). Much work has been done mapping these strata as the phosphorite sands have been the subject of great economic interest due to their high concentration of extractable phosphate (Riggs et al., 1982, Riggs et al., 1985, DPRA Report C-1599, 1987). Within Onslow Bay, Pliocene (5.3-2.58 Ma) and younger strata are present only as fluvial mud and sand channel fill deposits (Hine and Snyder, 1985) and scattered indurated limestone gravels, rubble-blocks and mesa-like platforms which serve as caprocks for modern marine hard bottoms (Mearns, 1986, Riggs et al., 1986, Snyder et al., 1988, Riggs et al., 1996). Holocene (12,000 years - Present) sediment occurs only as a patchy, thin veneer of surficial material that varies from fossiliferous limestone gravels and shell hash to reworked fine sands derived from older sedimentary strata (Riggs et al., 1996).

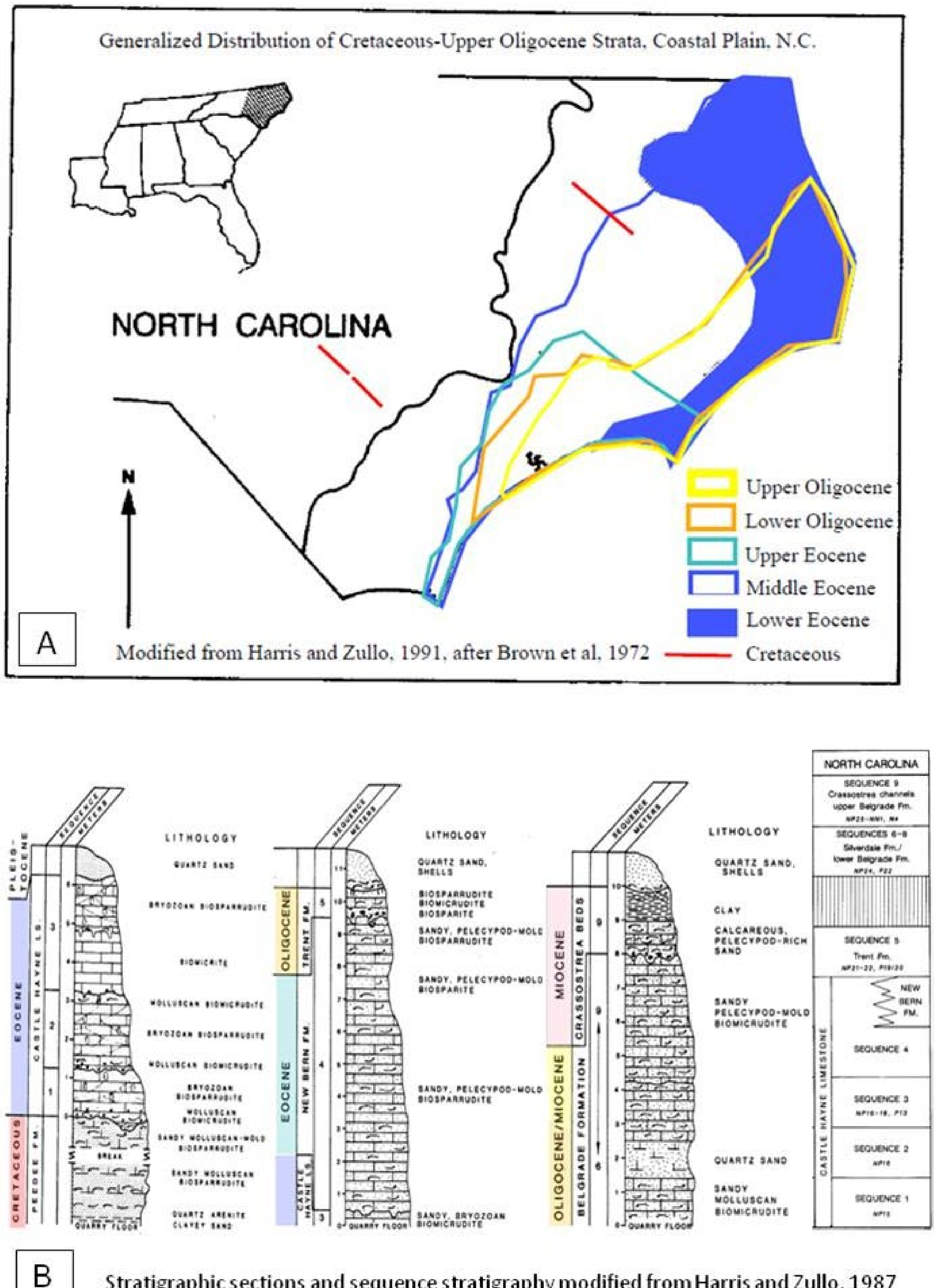


Figure 6. Distribution of Cretaceous-Oligocene strata within the Coastal Plain, N.C. and lithologic record of early Tertiary marine transgressional events.

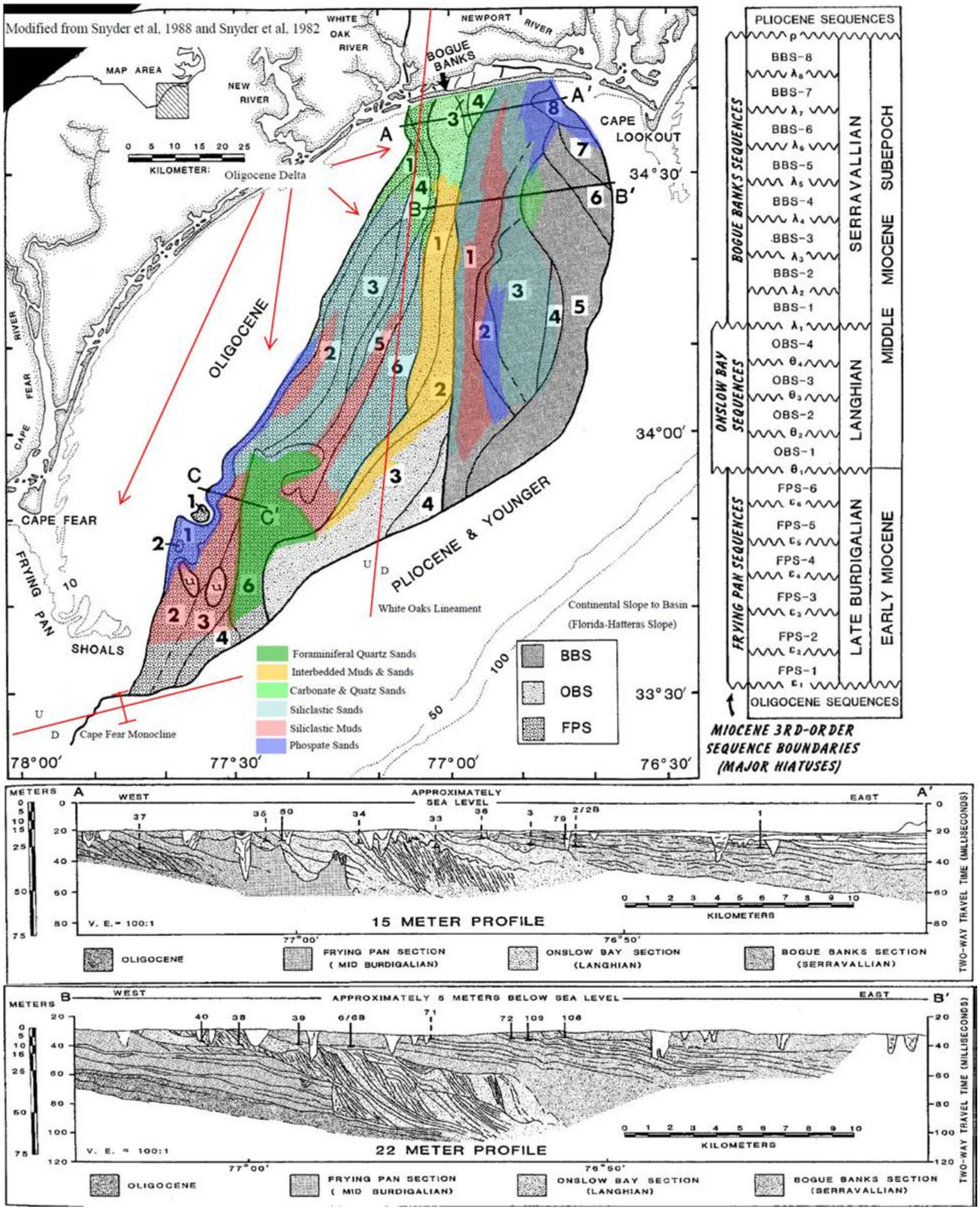


Figure 7. Seismic stratigraphy and lithology offshore Onslow Bay (modified from Snyder et al., 1988 and Snyder et al., 1982).

3.5 Geomorphology Topsail Island and Onslow Bay

Topsail Island is a modern, sediment starved, migrating, transgressive barrier island (Cleary, 2002, Backstrom et al., 2001) within the North Carolina Southern Coastal Province (Riggs and Ames, 2003). The island has a 22-mile, straight and relatively narrow, northeast trending shoreface that reflects a southwesterly longshore sediment transport (Cleary and Pilkey, 1996, Pilkey and Neal, 2009). The island lies between two active southwestward migrating inlets; New River Inlet (Sault, 1999) and New Topsail Inlet (McLean and Cleary, 2007). Between 1856 and 1980, the north side of the island has been migrated south on average 1.3 feet/year, while the south side (Figure 8E and F) has experienced periods of accretion and erosion (Cleary and Pilkey, 1996). The barrier island is separated from the mainland by Stump Sound and the AIWW. Historical records (circa 1870's) indicate that Topsail Island once consisted of three islands, separated by natural inlets that water mixing between Stump Sound and Onslow Bay (Pilkey and Neal, 2009). The width from the shoreface to the back barrier side ranges from 165-1,155 feet with little elevation gain (<5 feet), resulting in the formation of overwash terraces over much of the island's extent (Figure 8A and B). Topsail Island is located within a high storm hazard zone; the frequency of storms, lack of fluvial sediment input, and interruption of longshore transport has resulted in the erosion of nearly all dunes (Figure 8A, B, C, and D) and grasslands on the island (Rauscher and Cleary, 2000, Cleary, 2002, Pilkey and Neal, 2009). From 1,775 to 2,007 there have been 82 documented (Pilkey and Neal, 2009) storms that have impacted or caused damage to Topsail Island and surrounding vicinity. Recent hurricane activity (1996-1999) has created at least seven temporary breaches or swash channels across the island, requiring bridge replacements and road repairs to maintain evacuation routes (Rauscher and Cleary, 2000, Pilkey and Neal, 2009). Natural sediment accumulation/recovery onto the shoreface has not kept pace with erosion and sea-level rise (Horton et al., 2007), resulting in shoreline recession and property loss (Pilkey and Neal, 2009, Riggs and Ames, 2009, Cleary, 2002, Backstrom et al., 2001 and Rauscher and Cleary, 2000). Modern sediment accumulation for Topsail Island and Onslow Bay is negligible due to the following: 1) low sediment loads carried by small, swampy, black water streams, 2) sediment trapping within modern back barrier marsh environments, 3) minimal sediment exchange between cape-shoal embayments along the continental shelf (Riggs et al., 1996, Cleary, 2002). Theiler et al. (2000) suggest that overall, the seafloor of Onslow Bay is actively eroding away, producing only a thin (<3 feet) veneer of transitory sand. With respect to individual barrier islands such as Topsail, Theiler et al. (2000) contend these sediment-starved islands formed atop indurated Oligocene to Cretaceous sediment or atop estuarine muds, resulting in conditions that promote high rates of shoreline recession and negligible sand production.

The nearshore of Topsail Island is a submarine headland shoreface in the sense of Riggs et al. (1996), in that it contains subaerially exposed bedrock that is incorporated into the nearshore environment as hard bottoms (Figure 9A). The bedrock comprising these hard bottoms is laterally contiguous; the stratum continues beneath the beachfront and can be traced inland behind the barrier system (Cleary and Hosier, 1987, Clark et al., 1986, Riggs et al., 1996). Offshore, the hard bottoms are comprised of sandy to clayey fossiliferous limestone, mantled by actively eroding, wave-cut limestone scarps, and deeply undercut ledges (Crowson, 1980). The limestone was initially correlated by Crowson (1980) to the Lower Miocene Belgrade Formation of Ward et al. (1978); however, later interpretations consider this rock to be part of the Oligocene Silverdale Formation (Riggs et al., 1996). These limestone-cored hard bottoms form ridges which are oriented at acute angles to the shoreface of Topsail Island (Riggs et al., 1996). The hard bottom surfaces (Figure 9A) are constantly eroded by wave energy and by benthic burrowing organisms (Crowson, 1980). The degree to which they form steep scarps, ledges, caves and platforms (Figure 9B) is controlled by the relative hardness and cementation of the materials comprising them (Riggs et al., 1996). Bioerosion and reworking of the older strata comprising these hard bottoms contribute fine sand and shelly-gravels to transitory Holocene deposits (Crowson, 1980, Riggs et al., 1996, Riggs et al., 1998, Cleary, 2002), which often become trapped between hard bottom scarps and troughs (Riggs et al., 1996, Riggs et al., 1998, Rauscher and Cleary, 2000). Though workers (Crowson, 1980, Riggs et al., 1996, Riggs et al., 1996, Riggs et al., 1998) agree that this mechanism contributes thousands of tons of material to the sediment budget; it is not volumetrically significant enough to forestall present-day shoreline recession impacting Onslow Bay barrier island communities (Riggs and Ames, 2009).

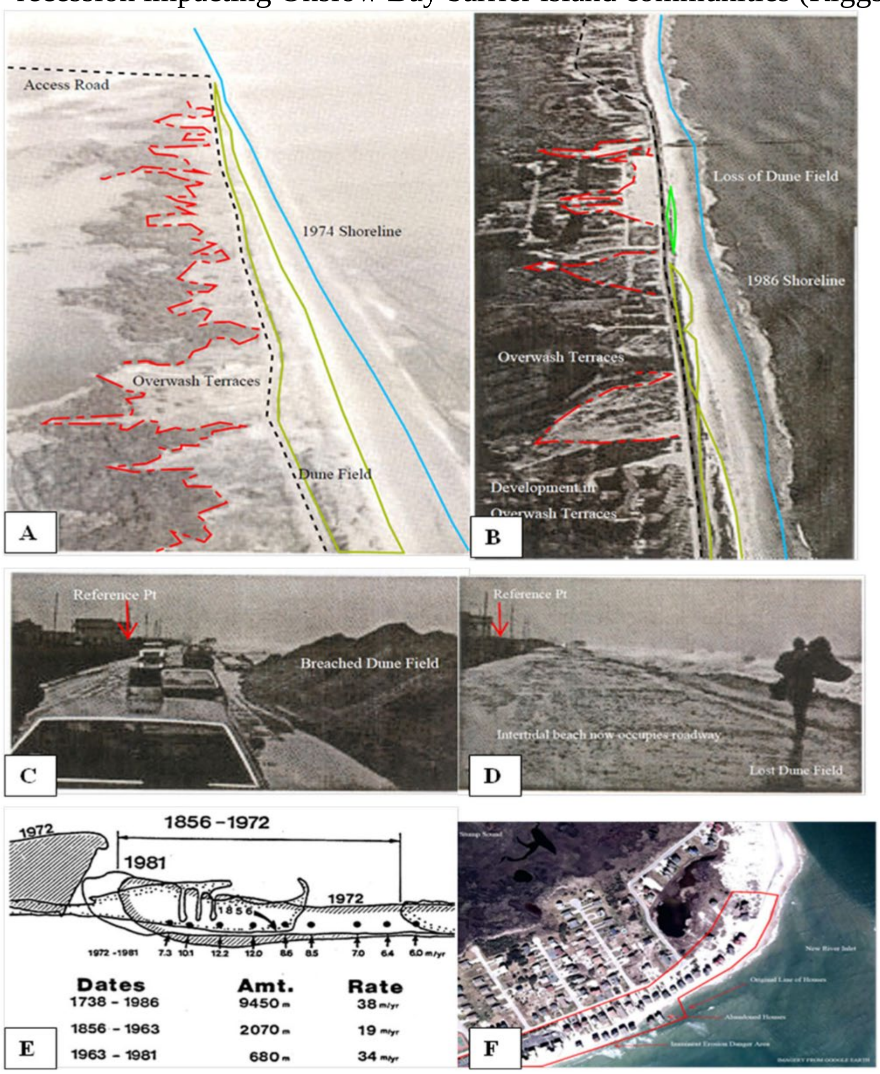


Figure 8. Dynamic geomorphic features on Topsail Island (modified from Cleary and Pilkey, 1996). A and B) The changing shoreline conditions and construction on overwash deposits. C and D) The erosion and loss of shoreface dunes. E and F) The inlet migration for New Topsail and New River Inlets.

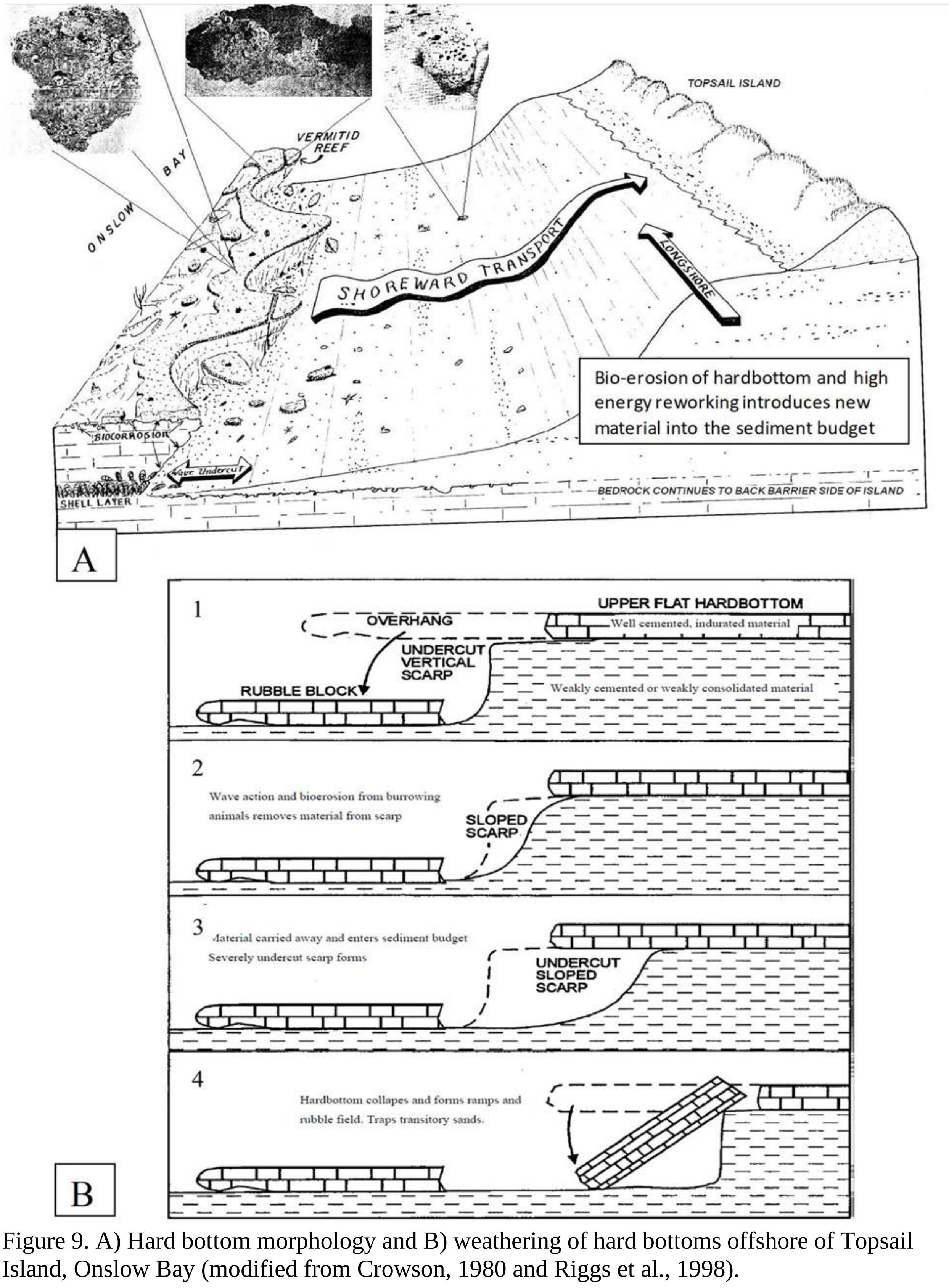


Figure 9. A) Hard bottom morphology and B) weathering of hard bottoms offshore of Topsail Island, Onslow Bay (modified from Crowson, 1980 and Riggs et al., 1998).

3.6 Site Geology

3.6.1 Background for Borrow site A Characterization

Borrow site A lies 2.5 miles south of New Topsail Inlet, 2.0 miles east of Rich Inlet, and extends offshore to a distance of 4.0 miles (Figure 10). The seafloor within the vicinity of the borrow site is floored primary by weathered Oligocene silty sandstone (Figure 10), outcroppings of Oligocene limestone hard bottoms (Cleary, 2002), and two paleofluvial channels, P1 and P2 (utilizing OSI naming convention, OSI, 2004). The largest hard bottom field lies 0.8 miles southeast of New Topsail Inlet and is comprised mainly of bio-eroded, moldic Oligocene limestone and siltstone (Cleary, 2002). Ocean Surveys, Inc (OSI) (2004) determined that this hard bottom and rock scarp field extends 7.8 miles to the northeast, parallel to the modern shoreline. Smaller southeast trending hard bottoms are located adjacent to the mouth of New Topsail Inlet, which are surrounded by a thin blanket (2 to 8 feet thick) interbedded silty to shelly sands. This unconsolidated material grades into interbedded silt and sand further offshore.

In order to confirm the presence of potential exposed limestone and siltstone outcrops within the study area offshore of Topsail Island, high resolution remote sensing surveys (i.e. sidescan sonar and multi-beam bathymetry) were conducted in both the nearshore environment (i.e. <30 feet Mean Lower Low Water, MLLW) and within the identified offshore borrow sites. Nearshore survey anomalies containing different back scatter returns or elevation change were labeled as “potential hard bottom” warranting future ground truth efforts to assess the presence or absence of hard bottom (Greenhorne and O’Mara, 2006 and 2007). Initial surveys conducted in the identified borrow sites offshore of Topsail Beach in 2004 did not identify any hard bottom but noted regions of coarse sand and shell hash sand waves and fine to silty sand with no relief (Hall, 2004). Additional surveys conducted in Borrow site A in 2011 identified regions of “potential hard bottom.” The following sections discuss the details associated with all work conducted offshore of Topsail Beach using remote surveying and subsequent ground truth efforts to confirm the presence or absence of hard bottom features in both the nearshore environment and offshore borrow sites (see Appendix C).

3.6.2 Nearshore Surveys

Nearshore side-scan sonar data collected from the shoreface to approximately the -30 feet MLLW contour offshore of Topsail Beach provided a visual representation of the change in density of the surface material on the ocean bottom. Interpretation of the side-scan sonar data identified several areas which had higher density material than the adjacent area. These high backscatter “finger-like” projections were located cross-shore throughout the survey area. Based on these density differences, the areas of high backscatter were considered “potential hard bottom” targets and were delineated for future ground truth investigation. Generally, these targets started approximately 800 feet offshore (2004 wet/dry line) and extended to the end of the survey (and presumably further offshore beyond the survey limit), located approximately 1,800 feet offshore.
Additional multi-beam surveys were conducted on these isolated targets and data interpretation of seafloor bathymetry indicated that areas of high backscatter with cross-shore orientation identified in the side-scan sonar survey were gradual seafloor depressions with approximately 1.5 feet vertical relief per 330 feet horizontal distance. In order to further characterize

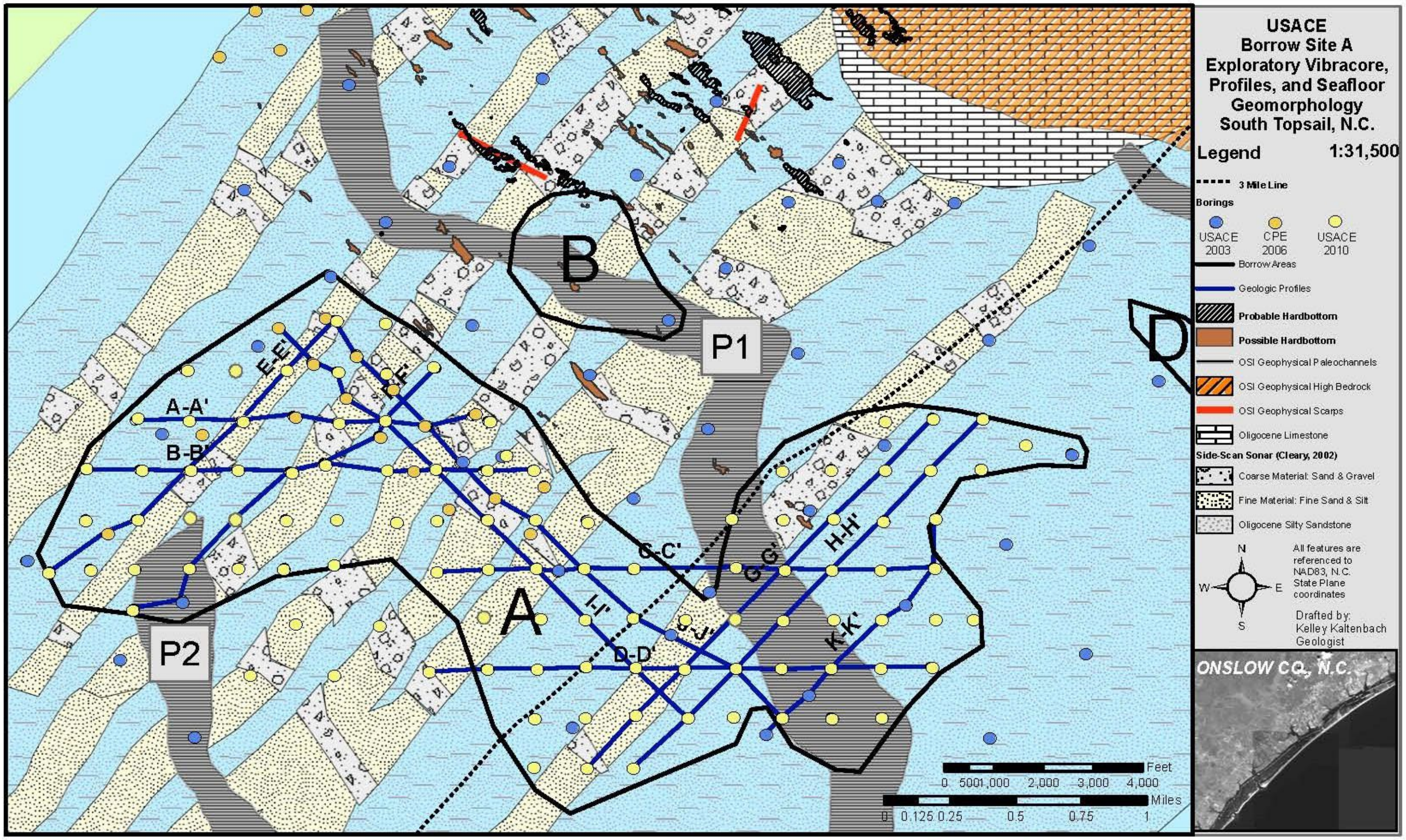


Figure 10. USACE Borrow Site A exploratory vibracore, profiles, and seafloor geomorphology.

the substrate of these depressional features, USACE coordinated with National Oceanic and Atmospheric Administration (NOAA) Fisheries to diver ground representative sites and gather surface sediment grab samples. Samples were retrieved from both within and outside of the identified depressions. Sediment samples retrieved outside of the depressions (areas of low backscatter) were characterized as fine grained sand; whereas samples retrieved from within the depressions (areas of high backscatter) were generally a coarser sandy shell hash and, in two samples, contained small (3.0 inch x 2.0 inch) limestone cobbles.

In addition to the work conducted off of Topsail Beach, similar nearshore survey work was conducted off of Surf City and North Topsail Beach (SCNTB) as a component of an adjacent Coastal Storm Damage Reduction project (CSDR). Similar anomalies were identified from the side-scan and multi-beam surveys. Divers were used to ground truth the features and concluded that they were not hard bottom resources but regions of coarse gravel and shell hash that extend as shallow, depressional features perpendicular to shore. Additionally, divers were able to capture video of the transitional regions of sediment grain size, and sediment samples were gathered both in and outside the features to confirm that the side-scan sonar acoustic signature documented a transition from fine- to coarse-grained sediment, not consolidated, hard bottom features.

The features identified in both the Topsail Beach and SCNTB remote sensing surveys and subsequent ground truth efforts are consistent with previously identified "rippled scour depressions (RSD)" (Cacchione et. al., 1984; Thieler et. al., 1999; Thieler et. al., 2001), "ripple channel depressions (RCD)" (McQuarrie, 1998), or "sorted bedform" (Murray and Thieler, 2004) features. Though termed differently throughout the literature, RSD, RCD, and sorted bedforms are considered interchangeable terms to identify the same geologic feature. According to McQuarrie (1998), an approximately 39 mi^2 area was surveyed using side-scan sonar, high resolution seismic, and vibracores on the shoreface and inner shelf of Onslow Bay. This study characterized the inner shelf off Topsail Beach as Tertiary and Pleistocene outcrops with a thin, discontinuous, loose surficial sheet of sediment. In addition to continuous quaternary fluvial channels traced shore perpendicular across the shoreface, wave and current action on the shoreface generates "ripple channel depressions." Additionally, a significant amount of historic side-scan data has been collected offshore of Topsail Beach (1992, 1994, and 1996) (Rob Thieler, Personal Communication; McQuarrie, 1998) which match well with the nearshore side-scan data conducted by Greenhorn and O'Mara (2006 and 2007). Evaluating these two data sets together provides some additional insight to the offshore extent and stability of these features. Considering that the data are spread over a 15 year timeframe and imagery from the data sets still match well, it appears that these features are fairly stable, at least over a decadal time frame (Rob Thieler; Personal Communication). This stability suggests that these features are maintained by the localized interaction of waves and currents and poorly sorted bed material. Specifically, these features represent a recurring, preferential morphologic state to which the seafloor returns after storm induced perturbations. This apparent stability is interpreted to be the result of interactions at several scales that contribute to a repeating, self-reinforcing pattern of forcing and sedimentary response which ultimately causes the RSD's to be maintained as bedforms responding to both along-and across shore flows. According to Dr. Bill Cleary (Personal communication), the presence of RSD's/sorted bedforms as identified through side-scan imagery off Topsail Beach are ubiquitous from Topsail Beach through Wrightsville Beach. Some of the side-scan imagery from Cleary (2002) is available in Figure 10. The high acoustic return from the side-scan sonar were interpreted to represent coarse-grained sands, shelly gravels or consolidated hard bottom material, while conversely, the low acoustic return indicated the presence of unconsolidated, fine-grained material such as silt and fine sand. Side-scan sonar imagery identifying the same features exists for Figure Eight Island and Lee/Hutaff Island.

Based on the comprehensive evaluation of the nearshore data collected through side-scan and multi-beam survey techniques, diver ground truth surveys, and additional historic offshore side-scan data, it was concluded that previously documented "potential hard bottom" targets are consistent with descriptions RSD, RCD, and sorted bedform features.

3.6.3 Borrow site A Survey Data

Borrow sites identified for the West Onslow (Topsail Beach) CSDR project were surveyed for "potential hard bottom" in 2004 in order to assure significant fishery resources were identified within the borrow site and that the project was formulated around avoidance of these resources. According to Hall (2004), high resolution side-scan sonar was used to define potential hard bottom locations throughout all six proposed borrow sites (A, B, C, D, E, and F) offshore of Topsail Beach. A review of these acoustic records indicated that there was no evidence of any hard bottom within all of the borrow site boundaries, including Borrow site A. Within survey regions of "moderate acoustic return" versus "weak acoustic return," grab samples were taken to ground truth the presence or absence of hard bottom. Grab samples of areas of harder return confirmed that these areas were coarse sand/shell hash associated with sand waves of 6 inches to 1 foot in height. The weaker acoustic returns were related to a fine to silty sand with little or no associated bottom relief or change.

The offshore environment of Topsail Beach, including the vicinity of identified borrow sites, is categorized as a high-energy shelf system with a thin and variable unconsolidated sediment covering low relief Oligocene limestone and siltstone hard bottoms (Cleary, 2002; Cleary, 2003). In 2011, USACE contracted with Geodynamics to perform a 100 percent coverage high-resolution survey of the seafloor surface (Figure 11) for evaluating underlying geology, sediment quantity, and potential hard bottom within Borrow site A. Results from the contract identified regions of "potential hard bottom" based on documented higher slopes (Figure 12) than the surrounding seafloor with high acoustic backscatter intensity suggesting "harder" or coarser material (Figure 13). The report noted that ground truth information was necessary to confirm the composition and structure of these features. The results from this report were very similar to previously documented "sorted bedform" features and are believed to be extensions of those documented in the nearshore environment. An additional 98 vibracores were completed in 2010 by the USACE Vessel SNELL in order to further refine sediment quantity and quality within Borrow site A. Several of the vibracores overlapped the areas documented by Geodynamics as "potential hard bottom" targets and served as means to ground truth the sediment type. The sediment samples from the vibracores within these targets confirmed that the area was unconsolidated sediment consisting of coarse to fine grained sand. Considering the results of the vibracore ground truthing and the consideration of the previously documented "sorted bedform" features just inshore of the borrow site, it is assumed that the regions identified by Geodynamics as "potential hard bottom" are actually extensions of the sorted bedform features extending offshore and perpendicular to the shoreface.

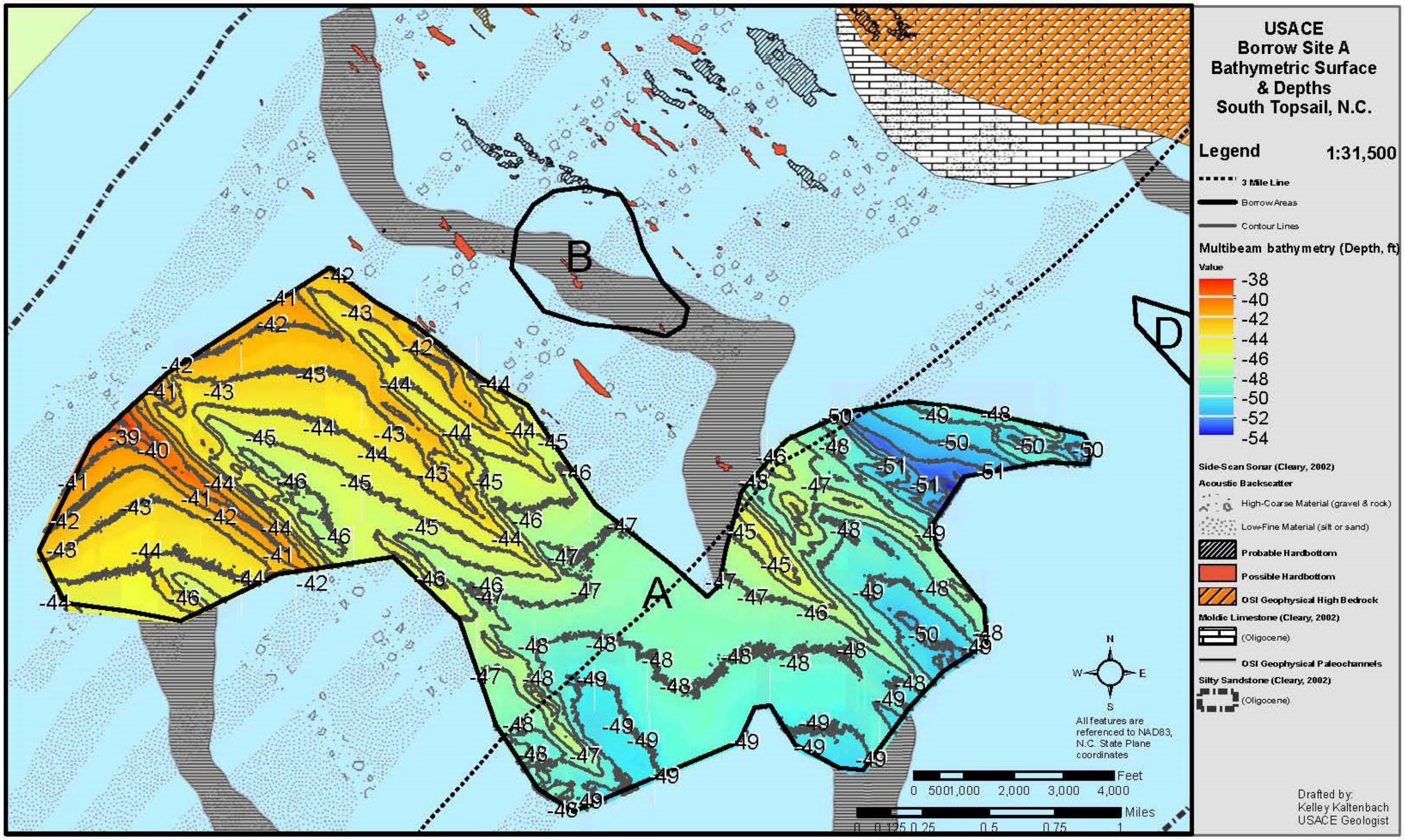


Figure 11. USACE Borrow site A bathymetric surface and depths.

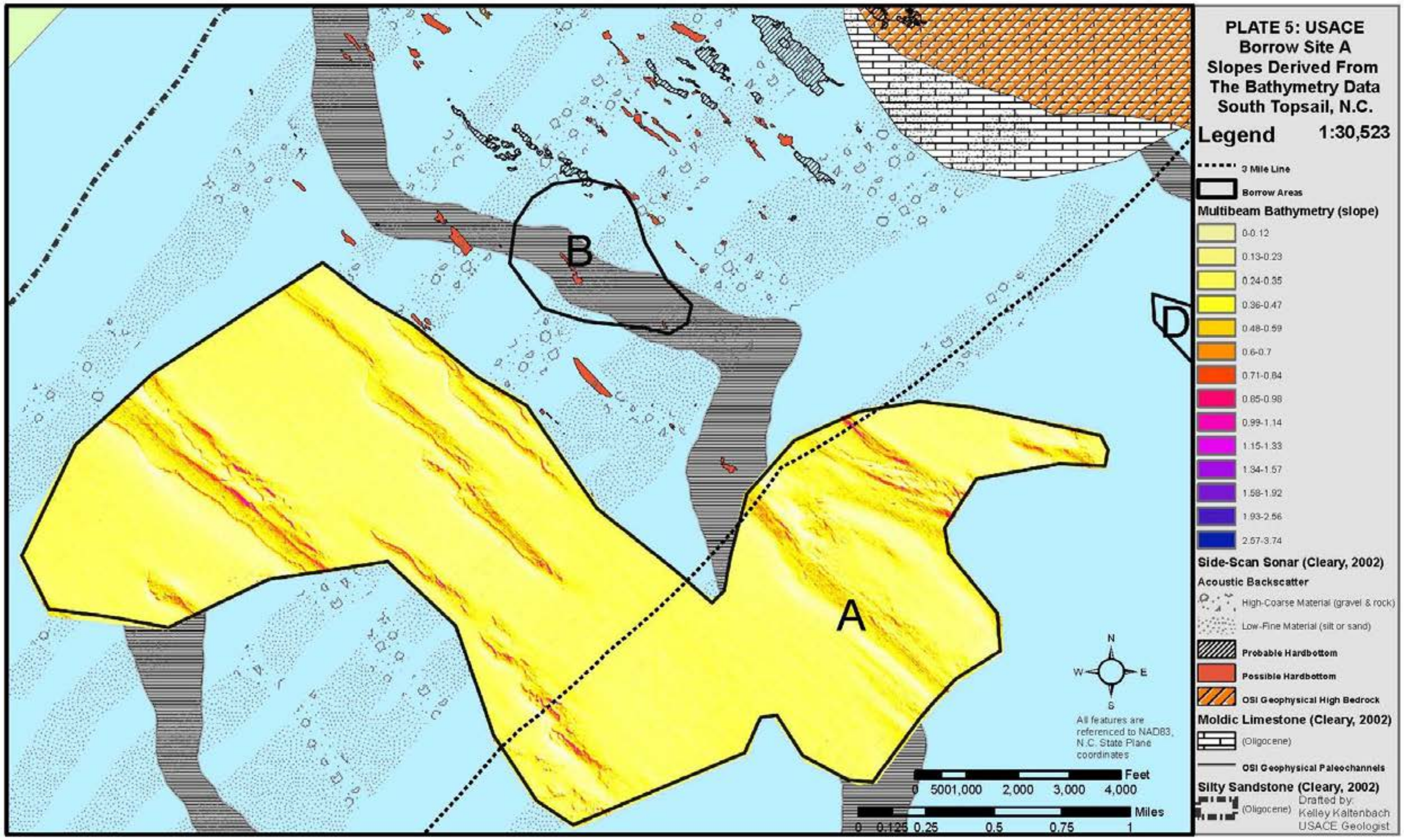


Figure 12. USACE Borrow site A slopes derived from the bathymetry data.

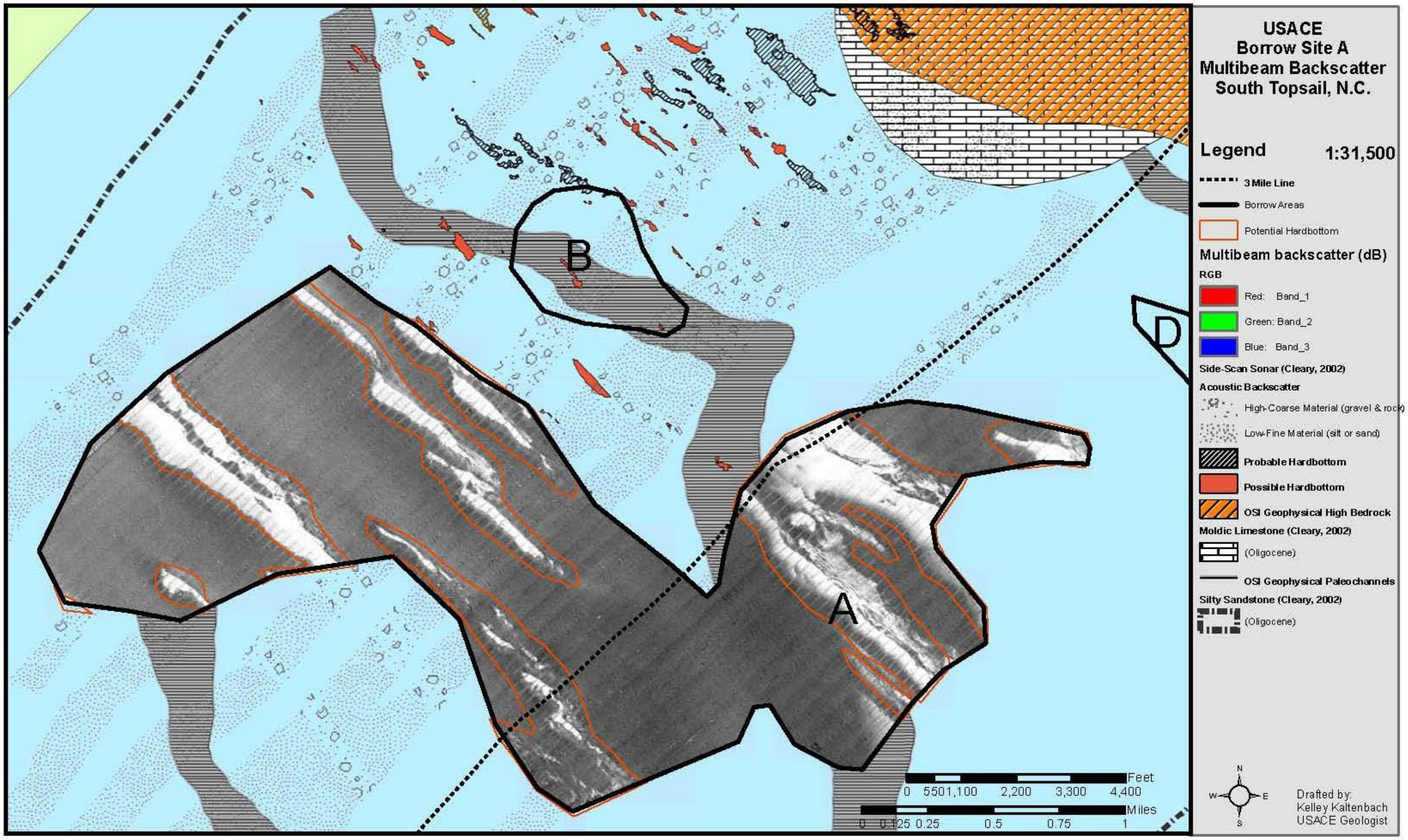


Figure 13. USACE Borrow site A multibeam backscatter.

In addition to the hydrographic survey, Geodynamics completed a geophysical survey of Borrow site A. The geophysical data were collected at 1,000 feet intervals using an EdgeTech sb512i compressed high intensity radar pulse (CHIRP) sub-bottom reflection sonar with EdgeTech Discover acquisition software. The CHIRP sub-bottom tracks lines are shown in Figure 14. The red circles indicate the start of each line, and the arrows indicate the tow direction. A CHIRP sub- bottom profile image was produced between each red circle. Figure 15 shows the image from the track line between TS52 and TS53 (highlighted in yellow on Figure 14). Along this track line there were nine vibracore borings that approximate locations are shown on Figure 10 and the borings are shown in Figure 16 as a 2D geologic profile fence report.

The CHIRP images were used to identify sub-bottom material changes and can assist in identifying suitable sediment material. Since vibracore boring had already been completed and analyzed prior to the completion of the geophysical survey the images were used to validate the compatibility analysis, which is discussed later in this report.

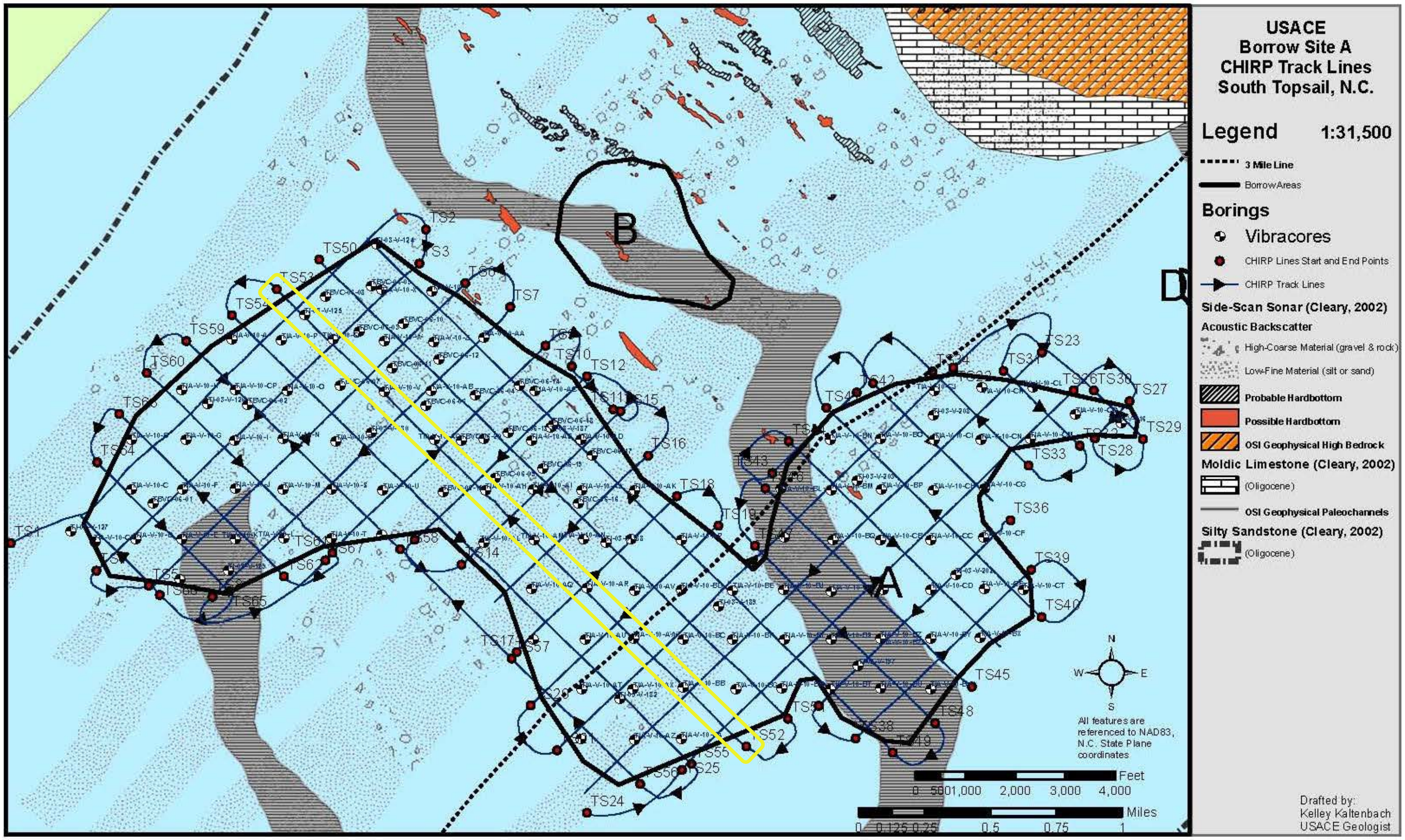
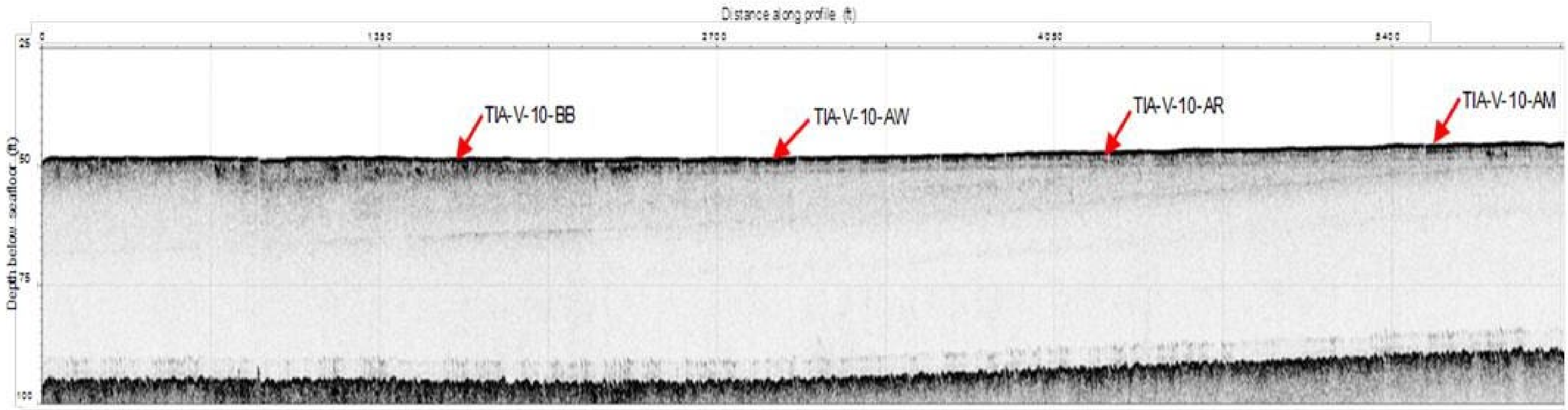


Figure 14. USACE Borrow site A CHIRP track lines.


Distance along profile (ft)
Depth below seafloor (ft)
TIA-V-10-BB
TIA-V-10-AW
TIA-V-10-AR
TIA-V-10-AM

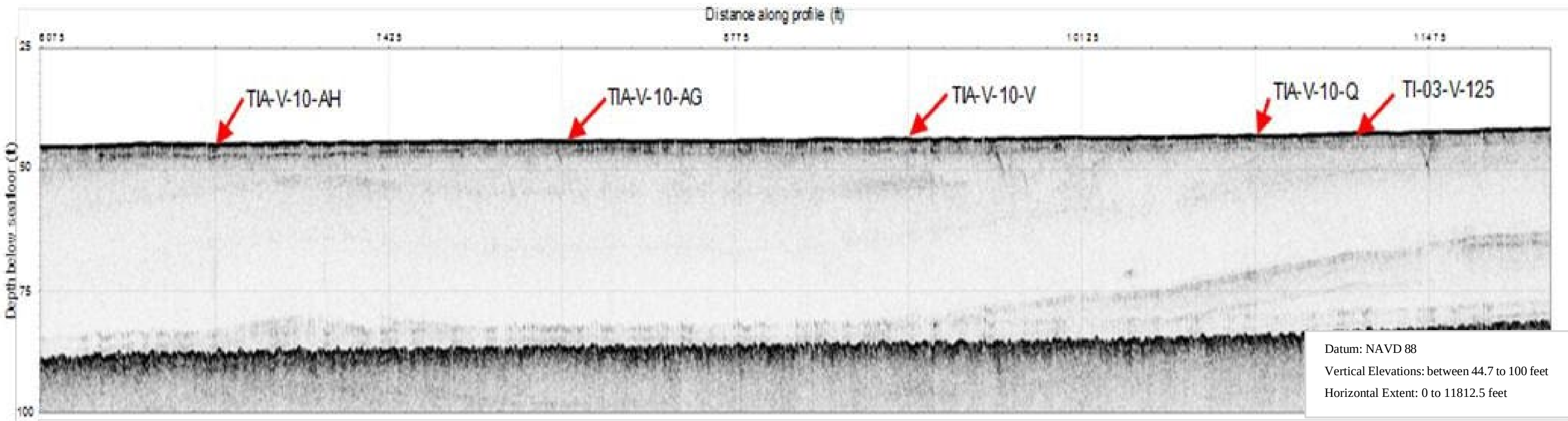

Distance along profile (ft)
Depth below seafloor (ft)
TIA-V-10-AH
TIA-V-10-AG
TIA-V-10-V
TIA-V-10-Q
TI-03-V-125
Datum: NAVD 88
Vertical Elevations: between 44.7 to 100 feet
Horizontal Extent: 0 to 11812.5 feet

Figure 15. The CHIRP image between TS52 and TS53 and the approximate vibracore borings along the track line.

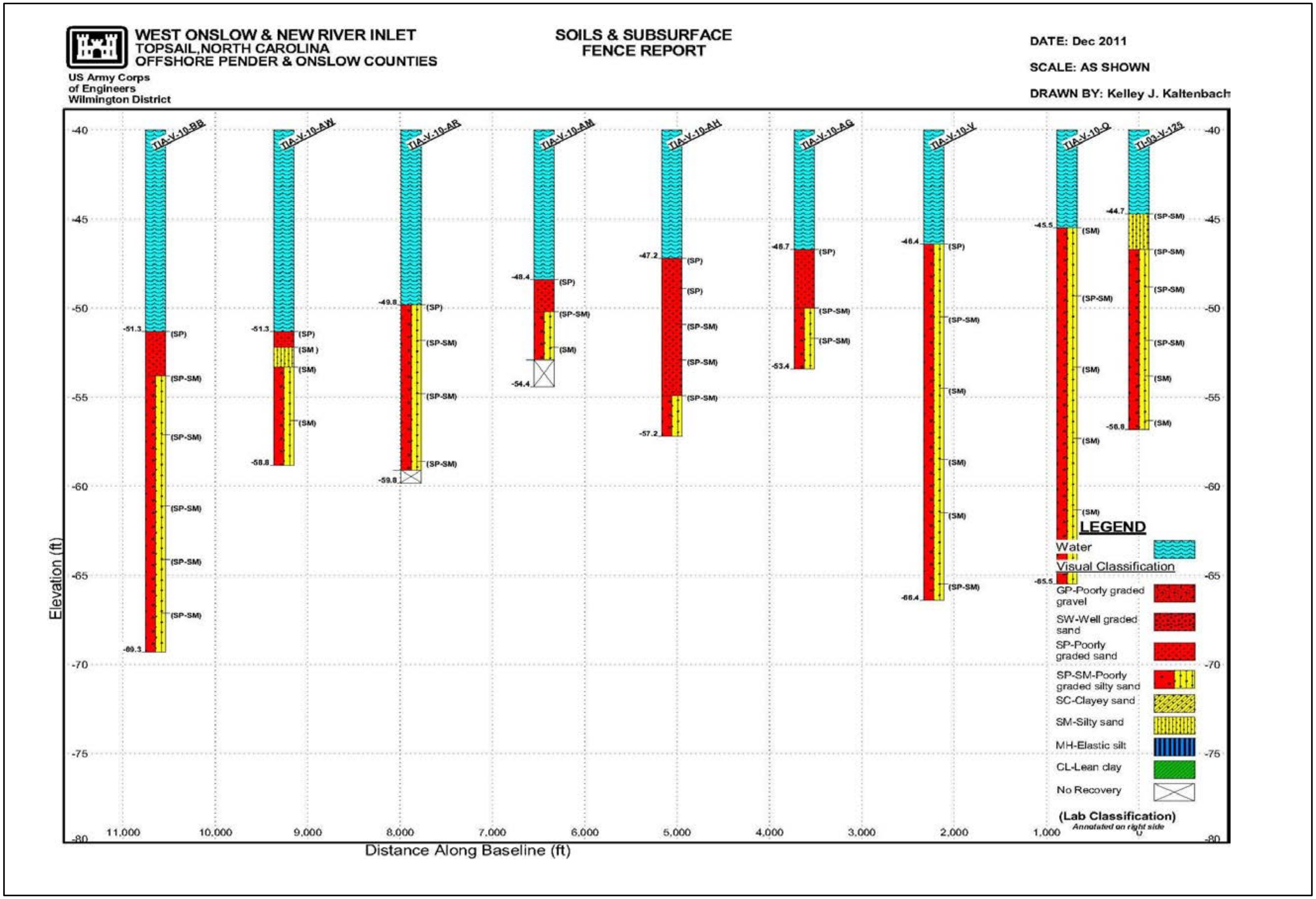

WEST ONSLOW & NEW RIVER INLET
TOPSAIL,NORTH CAROLINA
OFFSHORE PENDER & ONSLOW COUNTIES
US Army Corps
of Engineers
Wilmington District
SOILS & SUBSURFACE
FENCE REPORT
DATE: Dec 2011
SCALE: AS SHOWN
DRAWN BY: Kelley J. Kaltenbach
TIA-V-10-BB
TIA-V-10-AW
TIA-V-10-AR
TIA-V-10-AM
TIA-V-10-AH
TIA-V-10-AG
TIA-V-10-V
TIA-V-10-Q
TI-03-V-125
Elevation (ft)
Distance Along Baseline (ft)
LEGEND
Water
Visual Classification
GP-Poorly graded gravel
SW-Well graded sand
SP-Poorly graded sand
SP-SM-Poorly graded silty sand
SC-Clayey sand
SM-Silty sand
MH-Elastic silt
CL-Lean clay
No Recovery
(Lab Classification)
Annotated on right side

Figure 16. 2-D geologic profile fence report for vibracore borings along track line TS52 to TS53.

4.0 Methodology

4.1 Native Beach Sampling

The characteristics of the native beach material at Topsail Island were determined through an extensive sampling program performed in 2003 during the feasibility phase. The sampling of the native beach material was concentrated in two areas. The foreshore, which extends from mean low water (approximately 1.9 feet below National Geodetic Vertical Datum, NGVD 29, in the study area) landward to the seaward toe of the dune and the offshore area, which extends seaward from mean low water to a depth of 23 feet below NGVD 29. The foreshore and offshore samples were collected at approximately 5,000 foot intervals along the study area in order to evaluate grain size differences. Grab samples were collected by USACE along each of the six transects (see Figure 17) at the surface at the following elevations: Toe of the Dune, Crest of the Berm, Mean High Water (MHW) (see Figure 18 for a definition sketch of terminology), Mean Sea Level (MSL), Mean Low Water (MLW), and 12 samples collected seaward of MLW starting at elevation -3 feet and continuing at 2 foot depth increments from -4 to -24 feet. To recognize the15A North Carolina Administrative Code (NCAC) 07H.0312, two grab samples provided by CPE were combined with 11 of the USACE grab samples to develop the composite characteristic of each transect. The composite characteristics of each transect was then used to develop the composite of the native beach material, which is used in the compatibility analysis of the borrow material. The 13 samples from each transect were from the Dune, Toe of the Dune, Crest of the Berm, Mean High Water (MHW), Mean Sea Level (MSL), Mean Low Water (MLW), one sample landward of the MLW, and six samples seaward of the MLW line (-6.0, -8.0, -12.0, -14.0, -18.0, -20.0 feet).

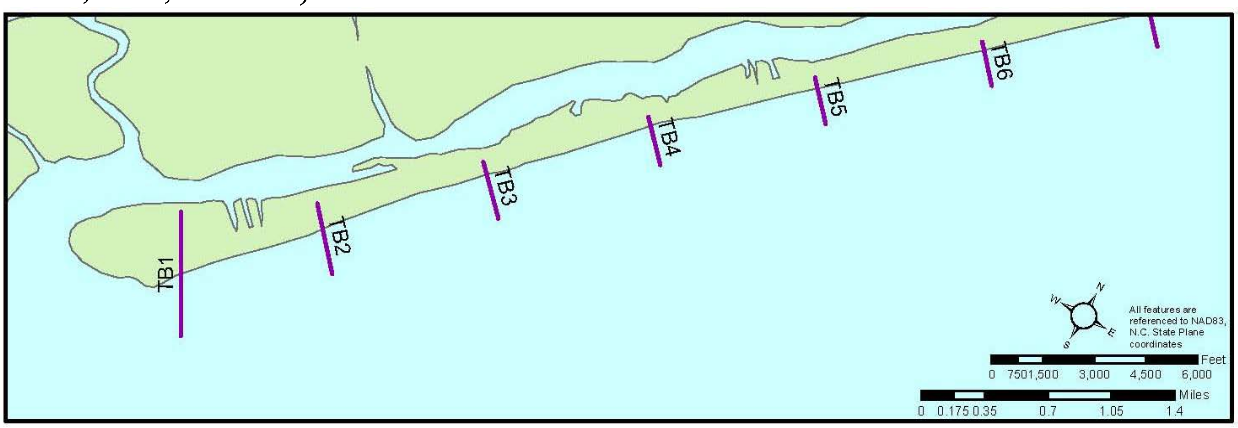


Figure 17. Topsail Beach native beach 5,000-foot intervals.

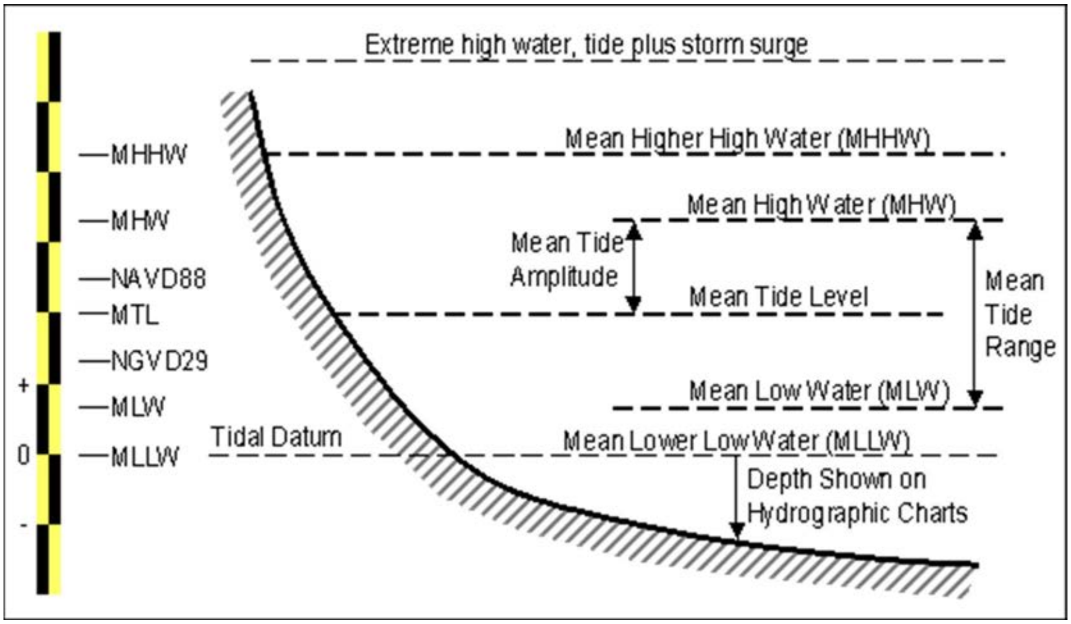


Figure 18. Definition sketch for NOAA tide level terminology [Image]. (2011). Retrieved May 17, 2012, from: http://www.fhwa.dot.gov/engineering/hydraulics/hydrology/hec25c6.cfm

Note: The mean grain sizes of the native and borrow site materials are reported in phi (N) units in this report where phi is related to the grain size as follows:

$N = -\log_2(d)$
where:
d = grain size in millimeters (mm)
$\log_2$ = logarithm to the base 2

Since the distribution of the sand samples can generally be represented as log-normal distributions, the standard deviations and variances of the particle size distributions are reported in phi units. Topsail Beach native beach mean phi value was 2.15 ± 0.66 and the composite data from the samples had a mean of 1.0 percent fines and 11 percent shell. The composite results from each of the sampling intervals are listed in Table 1 along with the overall composite result for the native beach.

Table 1. Native beach sampling results for Topsail Beach.

Sampling Transect	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	% Shell
TB-1	2.26	0.55	0.9	9
TB-2	2.18	0.72	0.8	13
TB-3	2.20	0.58	0.7	9
TB-4	2.02	0.75	0.8	13
TB-5	2.09	0.69	1.4	12
TB-6	2.13	0.69	1.1	10

Topsail Native Beach Composite	
Mean (phi)	**2.15**
Std Dev (phi)	**0.66**
Weight % fines passing #230	**1.0**
Visual % Shell	**11**

4.2 Subsurface Sampling at Borrow Site A

The 2003 and 2010 subsurface investigations were performed using the USACE Vessel SNELL and an Alpine model 270 Vibracore. The vibracore machine is a self-contained pneumatic powered vibratory corer that has a 20-foot metal barrel into which a clear Lexan 3 7/8-inch diameter liner (vibracore tube) is inserted for collecting sediment. The liner is held in place by a metal shoe that is screwed onto both the liner and metal barrel. A cutting edge is included in the metal shoe. The vibracore machine uses a pneumatic powered vibrator mounted at the uppermost end of the vibracore barrel. The machine is mounted in a stand that can be lowered to the seafloor by a crane. When the vibracore is activated the vibracore barrel vibrates into the unconsolidated sediment and a disturbed sediment sample is retained inside the liner. In general, vibratory drilling collects 10 to 20 feet of sediment unless refusal is encountered. Refusal can occur when the penetration rate of the vibracore is less than 0.01 feet/second. The survey-grade HYPACK navigation system on the USACE Vessel SNELL is used to determine the boring locations. The seafloor bottom elevation is determined by measuring water depth from the water line to the subsurface, with water line datum as 0.0 feet. The recorded water depth is then corrected to MLLW using NOAA-verified tidal data for the date and time for which the vibracore was drilled. Once tide-corrected, the recovered vibracore tubes are ready for field classification and sample processing.

Note: After processing was complete the 2010 borings were converted to NAVD 88 based on the survey data provided by Geodynamics (Geodynamics, 2011; Appendix C).

The subsurface investigation performed by CPE in 2006 used a similar methodology for collecting sediment from the seafloor. CPE used an Alpine model 271B Vibracore for collecting cores up to 20 feet in length. The Alpine model 270 and the 271B Vibracores collect sediment using the same general equipment and method.

4.3 Laboratory Testing for Borrow Site A

The USACE vibracore tubes were taken to the Wilmington District, Snow's Cut field facility, where they were cut open, logged, and field visually classified in accordance with the Unified Soils Classification System (USCS). Samples were collected from each tube at approximately 2 foot intervals or at each visible change of material. The retained samples were stored in jars and sent to a USACE certified soils laboratory for particle-size analysis. A particle-size analysis was conducted on each sample in accordance with ASTM Standard D 422, "Standard Test Method for Particle-Size Analysis of Soils" using the following 16 U.S. Standard sieve sizes: 3/4", 3/8", No. 4, No. 7, No. 10, No. 14, No. 18, No. 25, No. 35, No. 45, No. 60, No. 80, No. 120, No. 170, No. 200, and No. 230 sieve. Since the vibracore samples are disturbed samples, strength properties cannot be determined from the samples and are therefore not performed. In addition to the particle-size analysis, all the samples were classified using visual engineering soil classification in accordance with ASTM Standard D 2487, "Classification of Soils for Engineering Purposes (Unified Soil Classification System)" as required in Engineering Manual 1110-1-1804 and a visual estimation of the percent shell content was performed. Table 2 contains some of the USCS definitions pertaining to the materials documented within the borrow.

Table 2. USCS definitions (based on ASTM-2487).

Major Division		Group Symbol	Group Name	Criteria
$F_{200}<50$	Gravel $R_4/R_{200}>0.5$	GP	Poorly graded gravel	$F_{200}<5$; $C_u\geq4$, $1\leq C_z\leq3$
	Sands $R_4/R_{200}\leq0.5$	SW	Well-graded sand	$F_{200}<5$; $C_u\geq6$, $1\leq C_z\leq3$
		SP	Poorly graded sand	$F_{200}<5$, Does not meet the SW criteria of C_u and C_z
		SM	Silty Sand	$F_{200}>12$, PI<4
		SC	Clayey sand	$F_{200}>12$, PI>7
		SWSM	Well-graded sand with silt	$5\leq F_{200}\leq12$, satisfies C_u and C_z criteria of SW and PI>7
		SP-SM	Poorly graded sand with silt	$5\leq F_{200}\leq12$, does not satisfy C_u and C_z criteria of SW and PI<4
		SPSC	Poorly graded sand with clay	$5\leq F_{200}\leq12$, does not satisfy C_u and C_z criteria of SW and PI>7
$F_{200}>50$	Silts and Clays LL≥50	MH	Sandy silt	≥30% plus No. 200, % sand ≥ % gravel
		CH	Fat clay	<30% plus No. 200, <15% plus No. 200
			Fat clay with sand	<30% plus No. 200, 15-29% plus No. 200, % sand ≥ % gravel

Note: C_u = uniformity coefficient
C_z = coefficient of gradation
LL = liquid limit
PI = plasticity index
F_{200} = percentage finer than the No.200 sieve

R_4 = percentage retained on the No.4 sieve
R_{200} = percentage retained on the No.200 sieve

The CPE cores were field logged while vibracore operations were still being conducted (Finkle et al., 2008). Each core was wrapped in plastic and label prior to being transported to the CPE Wilmington, NC office. In the office the cores were re-logged in greater detail, photographed, and sampled at distinct layers for particle-size analysis. The CPE particle-size analysis of to the soil samples used 20 U.S. Standard sieve sizes and included a soil classification and a visual estimate of the shell hash for each sample.

5.0 Subsurface Investigation Results for Borrow Site A

5.1 Spatial Analysis

Spatial analyses were conducted using ArcMap and gINT software in order to delineate potential resource subsections within Borrow site A, as well as identify problematic zones containing undesirable material. The 2010 field and lab data, 2006 CPE, and selected 2003 USACE boring logs were input into the gINT geotechnical database program, which facilitated consistent and timely drafting of boring logs and geologic 2-D fence reports.

Eleven 2-D geologic profile fence reports were generated utilizing sediment data from the aforementioned borings (Figure 11). The intent of each profile is to verify the thickness of potentially useful strata for borrow and beach placement purposes. Each profile conveys the following information: ocean bottom, bottom of boring, graphical representation of the visually classified soils, and the laboratory soil classification in parenthesis. Interpretative weight should be given to laboratory classification over field visual classification; however, the laboratory data does not take into consideration discrete stratigraphic variations such as silt-filled lenses that raise the silt content of composited sandy soils. Therefore, these models are best approximations of the in-situ soil conditions.

Profile A-A’ (Figure 19) runs west to east across the northern portion of Borrow site A (see Figure 10 for the orientation for each profile within the borrow site). Ocean bottom sediment encountered generally consist of poorly-graded, silty fine sands, overlying silt and olive-green poorly graded silty sands, which grade eastward into coarser, poor to well-graded sands. Vibracores TIA-V-10-H, TIA-V-10-CP and TBVC-06-07 contain a thin veneer of poorly-graded (SP) sand and slightly silty sand (SP-SM) which overlies fine-grained silty sand (SM). The fine-grained material contained within TBVC-06-07 likely represents channel deposits related to paleofluvial channel P2. The olive-green poorly graded silty sand (SP-SM) within borings TIA-V-10-H, Q, V, AB, TBVC-06-04, 14 and TIA-V-10-AC is likely derived from well-indurated Oligocene silty sandstone described by Cleary (2002). East of vibracore TIA-V-10-V, the maximum depth of potential sand resource material varies from -52 to -58 feet NAVD 88, while west of TIA-V-10-V the maximum depth of potential sand resource material varies from -47 to -50 feet NAVD 88.

Figure 20 displays the borings along Profile B-B’ which runs west to east across the northern portion of Borrow site A. The soils encountered generally consist of coarse-grained, poorly-graded sand (SP) and fine, poorly-graded silty sand (SP-SM), which grade eastward into silt (MH) and silty sand (SM) riverine deposits found within paleofluvial channel P2. The silty soils within vibracore TIA-V-10-I are considered to be related those of TIA-V-10-CP and

TBVC-06-07 of Profile A-A’, in that they appear to be constrained within paleofluvial channel P2. East of TIA-V-10-I, the surficial sediments generally grades into medium-coarse grained, poor to well-graded shelly sand, which overlies fine-grained, poorly-graded, silty sand (SP-SM). The olive-green poorly-graded silty sand (SP-SM) that underlies the clean shelly sands (SP) of borings TIA-V-10-B, TIA-V-10-G, TIA-V-10-N and TIA-V-10-AD appear to be derived from the Oligocene silty sandstone described by Cleary (2002). East of the P2 paleofluvial channel and TIA-V-10-I, the maximum depth of potential sand resource material varies widely from -52 to -65 feet NAVD 88.

Profile C-C’ (Figure 21) runs west to east across the east-central portion of Borrow site A. Soils encountered generally consist of medium-coarse, poorly-graded sand (SP) and slightly silty fine sand (SP-SM), overlying silty sand (SM) and olive-green, poorly-graded, fine silty sand (SP-SM). The distribution of the olive-green SP-SM is likely controlled vertically and horizontally by the distribution of well-indurated Oligocene silty sandstone, described by Cleary (2002). Generally, the sandy material appears to become increasingly silty towards the east in the vicinity of vibracores TIA-V-10-CD and TIA-V-10-CC. It is interesting to note the presence of beach-quality, poorly graded sand (SP) in vibracores TIA-V-10-BK and TIA-V-10-BQ; though these borings lie within the mapped P1 paleofluvial channel, they may actually represent coarser grained point bar (stream bank) deposits. The presence of silty soils in TIA-V-10-CB and TIA-V-10-CC may indicate lateral depositional variation within paleofluvial channel P1. Maximum depth of potential sand resource material varies from -51 to -59 feet NAVD 88.

Profile D-D’ runs west to east across the southern portion of Borrow site A (Figure 22). Soils encountered generally consist of a veneer (0.5-5.0 feet) of medium-coarse, poorly-graded sand (SP) overlying olive-green, fine-grained poorly graded silty sand (SP-SM) and fine silty sand (SM). The olive-green SP-SM and SM silty sands contain variable amounts of silty horizons and silt-filled worm burrows. Based upon the mapping conducted by Cleary (2002) this strata is likely derived from well-indurated Oligocene silty sandstone. Beach quality sand appears to be constrained to borings TIA-V-10-AS, TIA-V-10-AU and the upper 5 feet of TIA-V-10-BC and TIA-V-10-BF. West of TIA-V-10-BF, the soils become increasingly silty, probably in response to their proximity to the north-south trending P1 paleofluvial channel that underlies the borrow site. The maximum depth of potential sand resource material varies from -58 feet NAVD 88 in the vicinity of TIA-V-10-AS and TIA-V-10-AU, to -52 feet NAVD 88 in the vicinity of TIA-V-10-BF.

Figure 23 displays the borings along Profile E-E’, which runs southwest to northeast across the northwestern portion of Borrow site A and the buried paleofluvial channel P2. Soils encountered generally consist of olive green to olive gray, fine-grained, poorly-graded silty sands (SP-SM), which grade northeast into thick deposits of silt (MH) and silty sands (SM) in boring TIA-V-10-I. Referencing Figure 11, the SP-SM sands within borings TIA-V-10-D through F and borings TIA-V-10-O through X are likely derived from indurated Oligocene silty sandstones described by Cleary (2002). The silty soils within boring TIA-V-10-I likely represents a paleofluvial channel deposit. Northeast of bring TIA-V-10-I, the silt (MH) and silty sand (SM) grades into an interbedded sequence of poorly-graded, silty sand (SP-SM) and silty sand (SM). Southwest of the paleofluvial channel P2 and TIA-V-10-I (Figure 11), the maximum depth of sand resource material varies between -47.5 to -62 feet NAVD 88.

Profile F-F’ (Figure 24) runs southwest to northeast across the north central portion of the borrow site and crosses the northern end of paleofluvial channel P2. In cross-section, borings TIA-V-10-CS and TI-03-V-120 contain medium to fine-grained, poorly graded (SP) to slightly silty sands (SP-SM), possibly related to a point bar or channel deposit. Boring TIA-V-10-K has limited sample return; based upon Cleary’s (2002) side-scan data, soft silty soils could have been encountered which were lost upon recovery. Northeast of boring TIA-V-10-M, soils encountered generally consist of medium-coarse, poorly-graded sand (SP) interbedded with fine poorly graded silty sand (SP-SM). These soils grade vertically into an olive-gray to olive-green, silty sand (SM) with depth. This olive-green silty strata is considered to be indurated Oligocene silty sandstone described by Cleary (2002). The maximum depth of sand resource material, northeast of TIA-V-10-K ranges from -50 to -56 feet NAVD 88. A peak of silty sand (SM) or silty sandstone may be encountered along profile at boring TBVC-06-06 at depth -49 feet NAVD 88.

Profile G-G’ runs southwest to northeast across the south central portion of the borrow site (Figure 25). Soils encountered generally consist of fine-grained, poorly graded silty sand (SP-SM) overlying silty sands (SM) which grades to the northeast into cleaner poorly graded sands (SP) and slightly silty sand (SP-SM). TIA-V-10-BJ contains silty sand (SM) indicative of paleofluvial channel deposits. Northeast of TIA-V-10-BP, sediments encountered appear to be olive-green, silty sands derived from the Oligocene silty sandstone described by Cleary (2002). Gravel-sized fragments of weakly cemented sandstone were recovered within boring TIA-V-10-CK, possibly correlative to the sandstone bedrock. The maximum depth of potential sand resource material ranges from -53 to -69 feet NAVD 88 in the vicinity of borings TIA-V-10-AZ and BB, -58 feet NAVD 88 in the vicinity of TIA-V-10-BQ, shallowing upward to -53 feet NAVD 88 in the vicinity of TIA-V-10-CI.

Figure 26 displays the borings along Profile H-H’, which runs southwest to northeast across the southeastern portion of the borrow site and crosses paleofluvial channel P1. Soils encountered generally consist of a thin veneer of transitory, poorly-graded shelly sands (SP) along most of the profile, overlying olive-green, fine-grained, poorly-graded silty sand (SP-SM) and silty sand (SM). The olive-green SP-SM material found beneath the surficial SP material along much of the profile is likely derived from well indurated Oligocene silty sandstone described by Cleary (2002). Silty sediment recovered from borings TIA-V-10-BR and TIA-V-10-CB likely represents fine-grained estuarine channel deposits related to paleochannel P1. The maximum depth of potential sand resource material along profile varies greatly between TIA-V-10-BG (-60 feet NAVD 88) and TIA-V-10-BR (-54 feet NAVD 88). Northeast of TIA-V-10-CH, the maximum depth of potential source material ranges from -54 to -56 feet NAVD 88.

Profile I-I’ (Figure 27) runs northwest to southeast across the central portion of the borrow site and it trends sub-parallel to the seafloor features mapped by Cleary (2002). Northwest of boring TBVC-06-03, the soil conditions are dominated by silty sand (SM). Southeast of TBVC-06-08, soil conditions are generally characterized by poorly-graded clean (SP) to slightly silty sands (SP-SM) overlying olive-green to olive-gray, fine-grained, poorly-graded sand (SP-SM) derived from highly indurated Oligocene silty sandstone bedrock on the ocean floor. The maximum depth of potential sand resource material southeast of boring TBVC-06-08 varies from -53 feet NAVD 88 at boring TIA-V-10-AB to -59 feet NAVD 88 at boring TIA-V-10-BC.

Profile J-J' was drafted adjacent to Profile I-I' in order to better constrain the central portion of the borrow site (Figure 28). Soil conditions encountered are very similar to those described in Profile I-I'. Generally, a thin and variable veneer of medium to coarse-grained, poorly-graded shelly sand intermixed with shelly gravel, overlies olive-green to olive-gray, fine-grained, poorly-graded silty sand (SP-SM) which is derived from the weathering of highly indurated, bio-eroded Oligocene silty sandstone. The percentage of silt within this stratum appears to be controlled mainly by the presence of silt-filled worm burrows (bioturbation) or the presence of thin silt-filled lenses. The southeastern portion of the borrow site in the vicinity of borings TIA-V-10-BI and BT contains finer-grained silty sands (SM) just below the surficial sand. The maximum depth of potential sand material varies from -52 to -66 feet NAVD 88; however, the average depth across profile is probably closer to -55 feet NAVD 88.

Figure 29 displays the borings along Profile K-K', which was drafted on the southeastern side of the borrow site in order to characterize soil conditions that were observed during the sampling procedure. The first three borings along profile, TI-03-V-190, TIA-V-10-BT and TI-03-V-197 contain significant amounts of silty to clayey soils, correlated to their proximity to paleochannel P1. Borings TIA-V-10-BZ, BZ2 (not shown), and TIA-V-10-CD contain interbedded fine-grained sand (SP-SM) and silty sands (SM). Northeast of TIA-V-10-CD, the surficial sand becomes cleaner and grades laterally into poorly-graded sand (SP), which overlies gray to olive-green silty to slightly silty sands. The maximum depth of potential source material ranges from -49 feet to -56feet NAVD 88. This profile generally contains borings with a thin layer of sand on top of material that is silty.

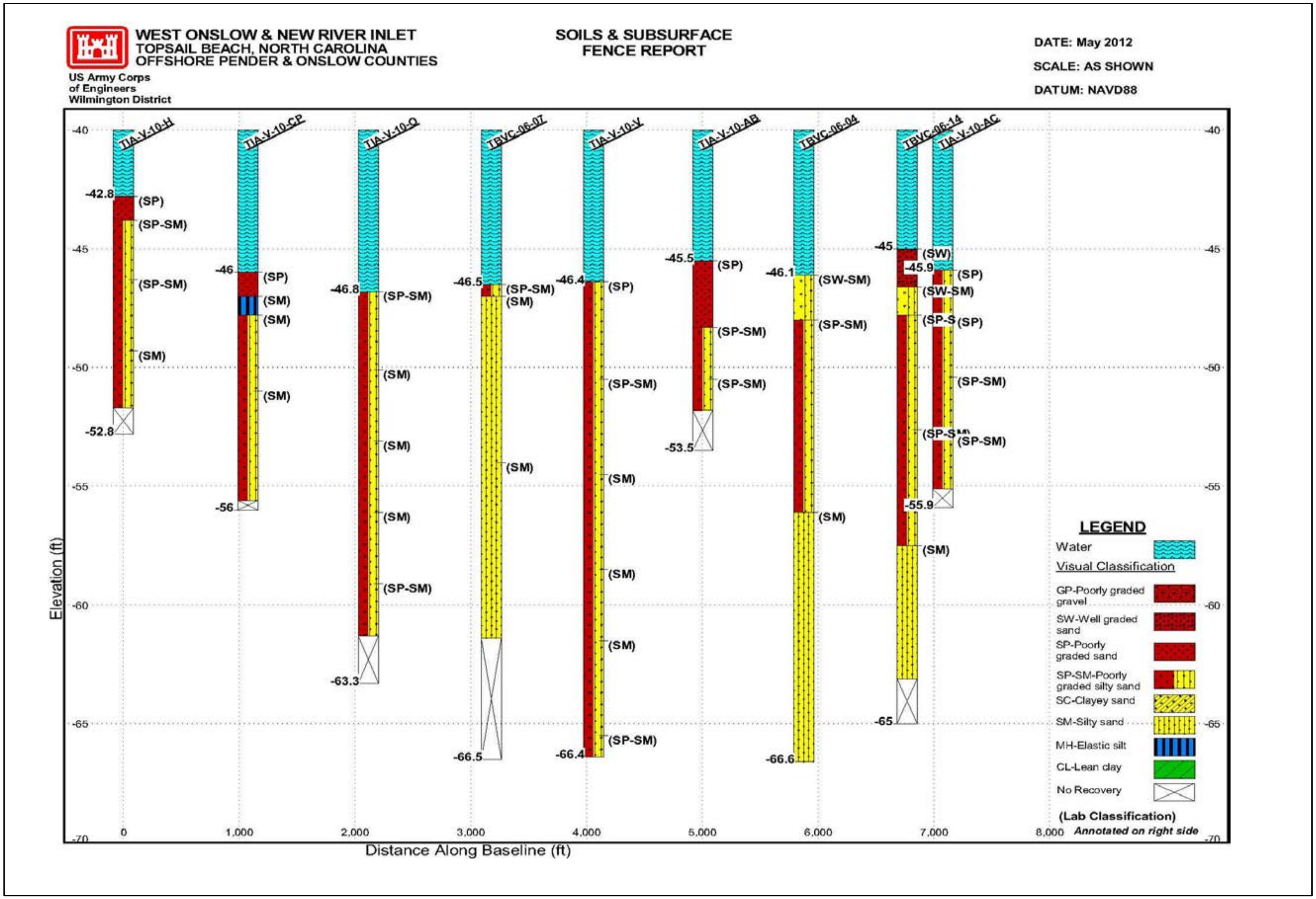


Figure 19. 2-D geologic cross section, profile A-A'.

A

A’

Figure 19. 2-D geologic cross section, profile A-A’.

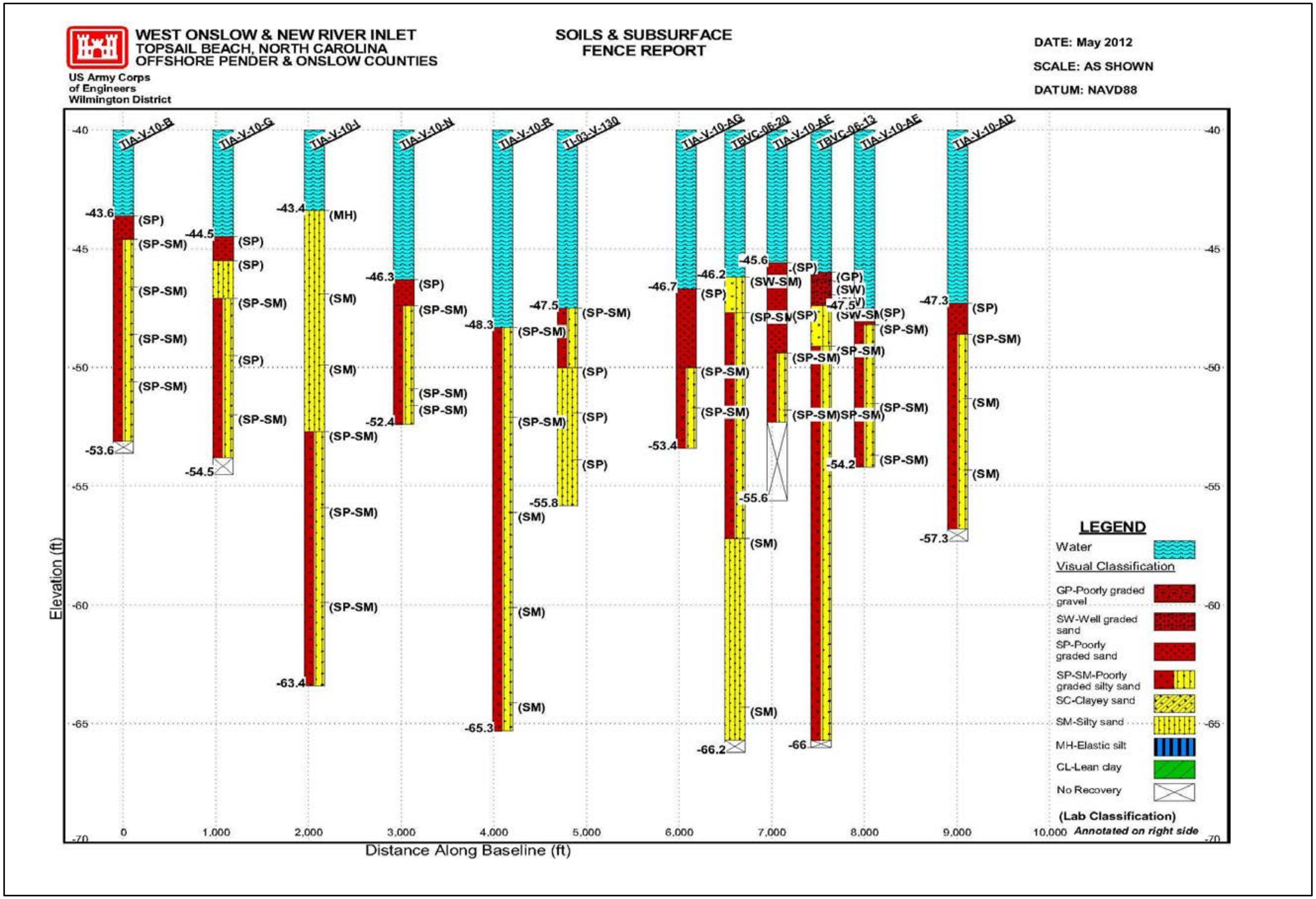


Figure 20. 2-D geologic cross section, profile B-B'.

B

B'

Figure 20. 2-D geologic cross section, profile B-B'.

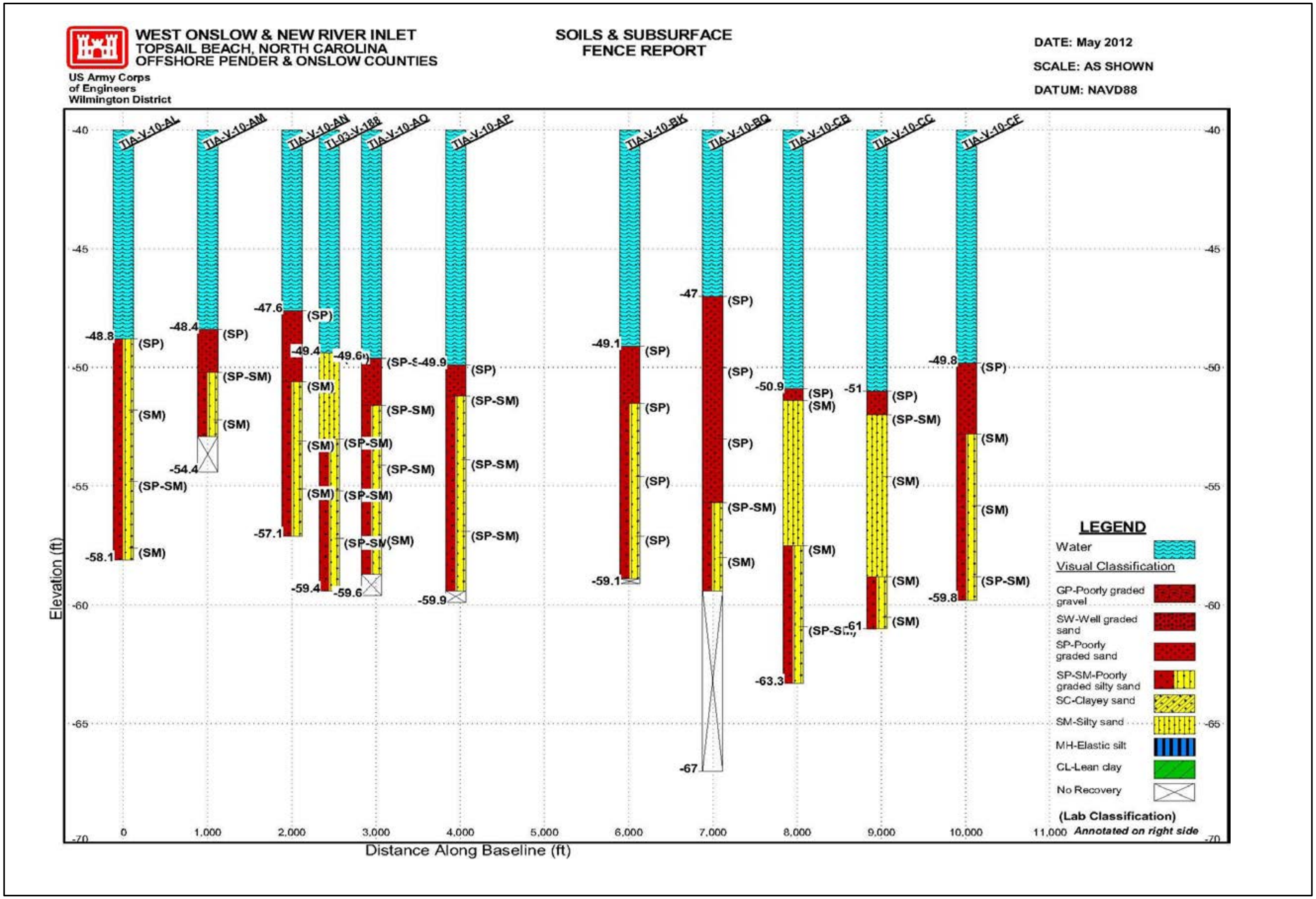


Figure 21. 2-D geologic cross section, profile C-C'.

C
C’

Figure 21. 2-D geologic cross section, profile C-C’.

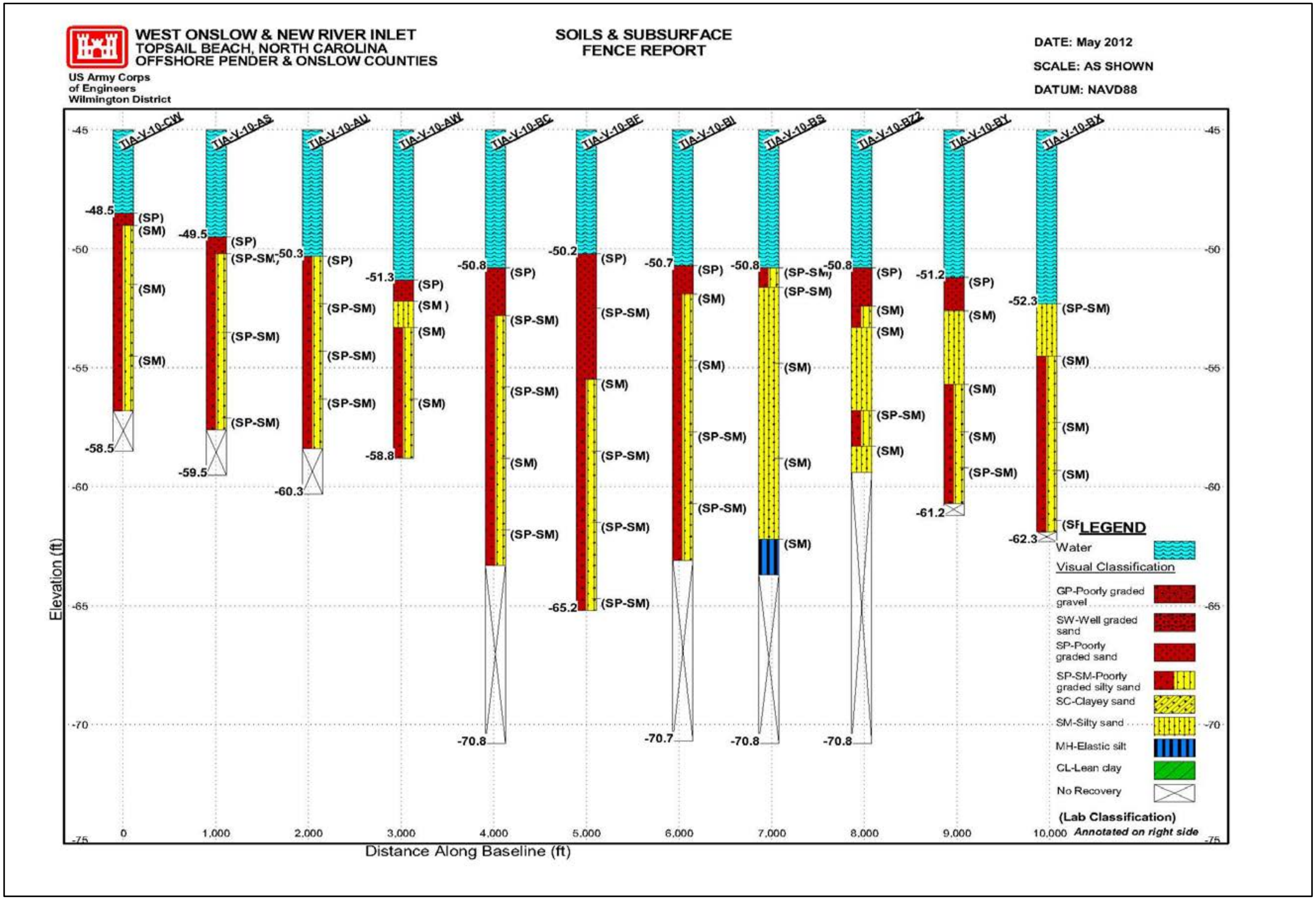


Figure 22. 2-D geologic cross section, profile D-D'.

D

D’

Figure 22. 2-D geologic cross section, profile D-D’.

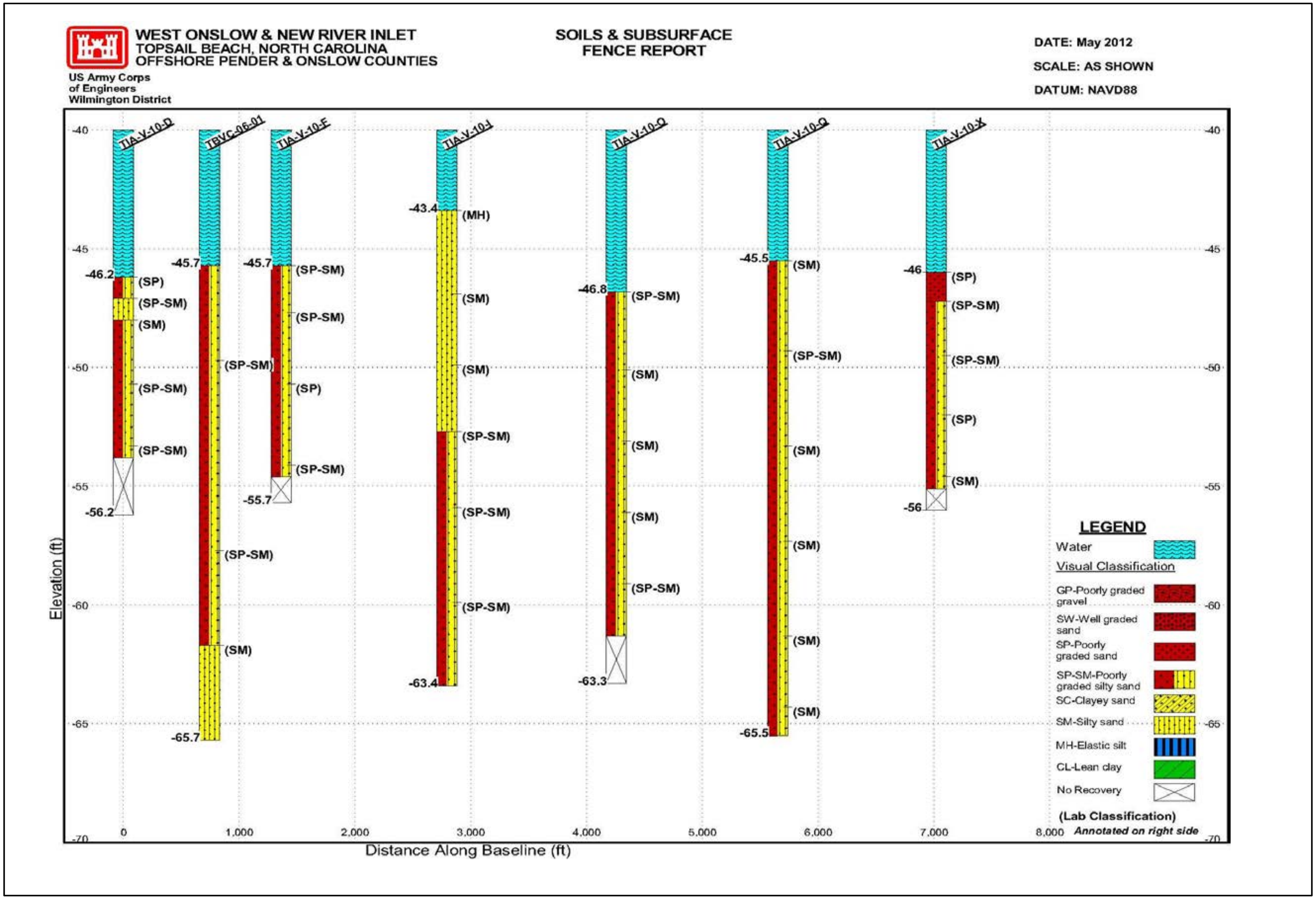


Figure 23. 2-D geologic cross section, profile E-E’.

E E’

Figure 23. 2-D geologic cross section, profile E-E’.

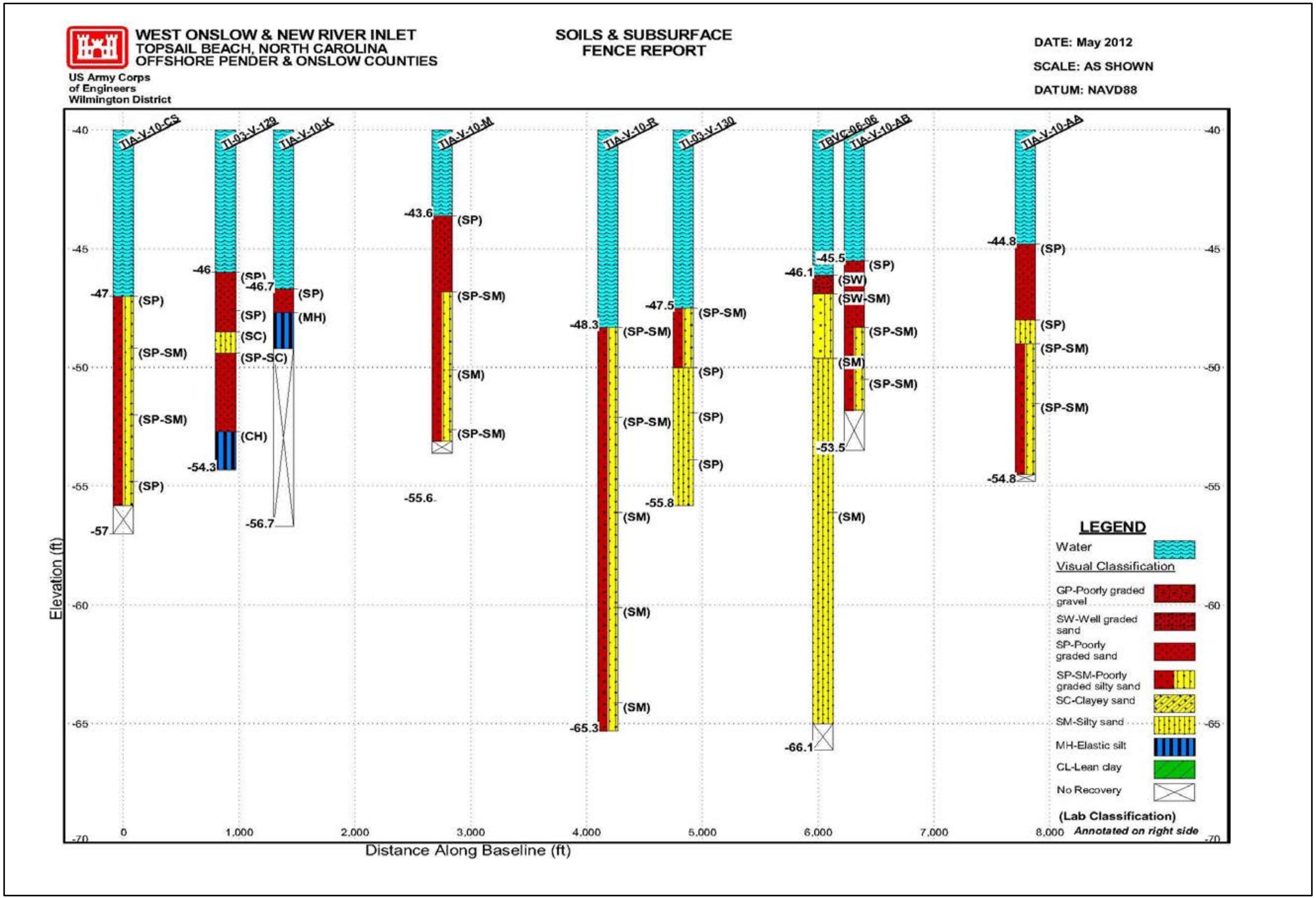


Figure 24. 2-D geologic cross section, profile F-F'.

F’
F

Figure 24. 2-D geologic cross section, profile F-F’.

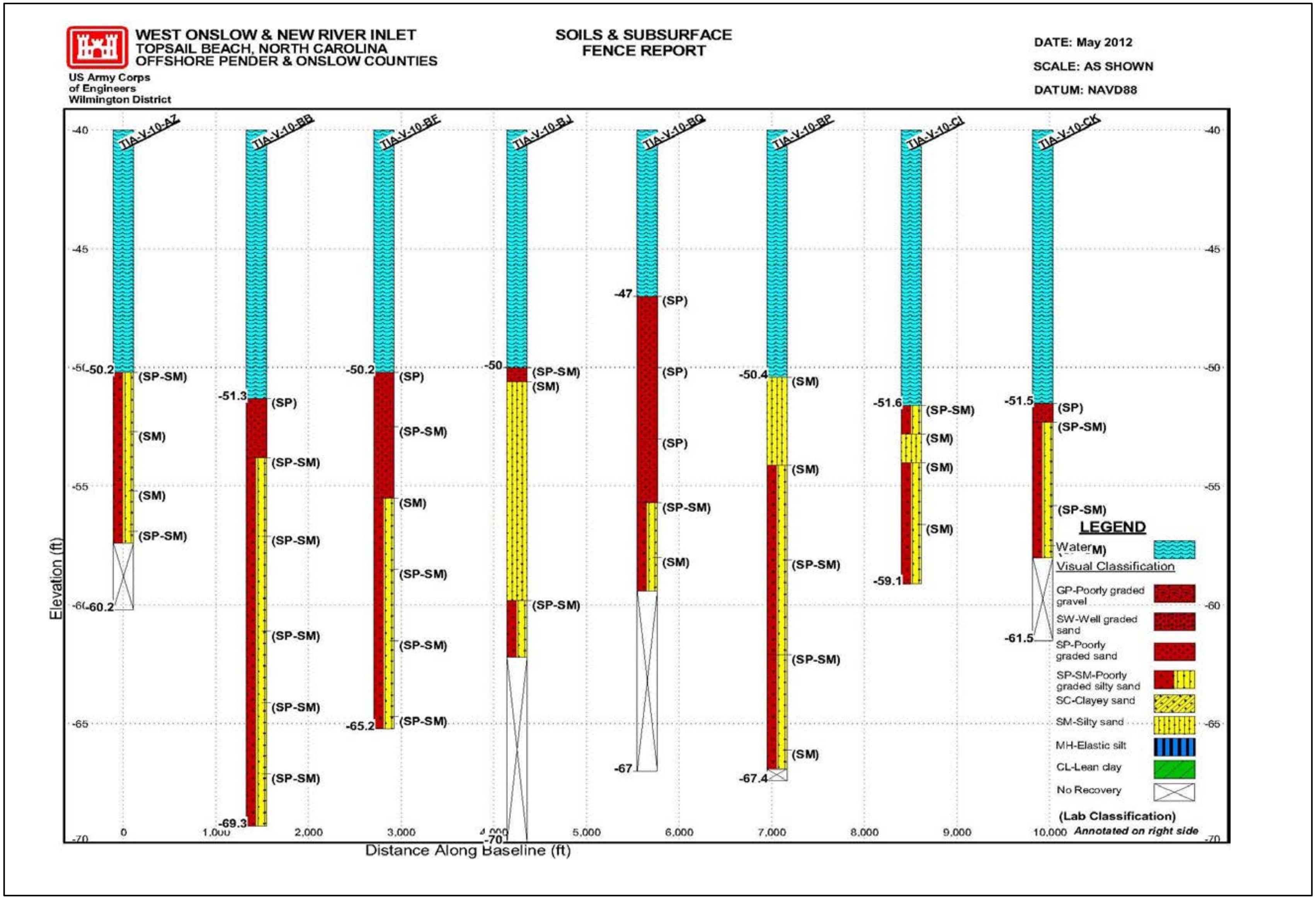


Figure 25. 2-D geologic cross section, profile G-G'.

G
G’

Figure 25. 2-D geologic cross section, profile G-G’.

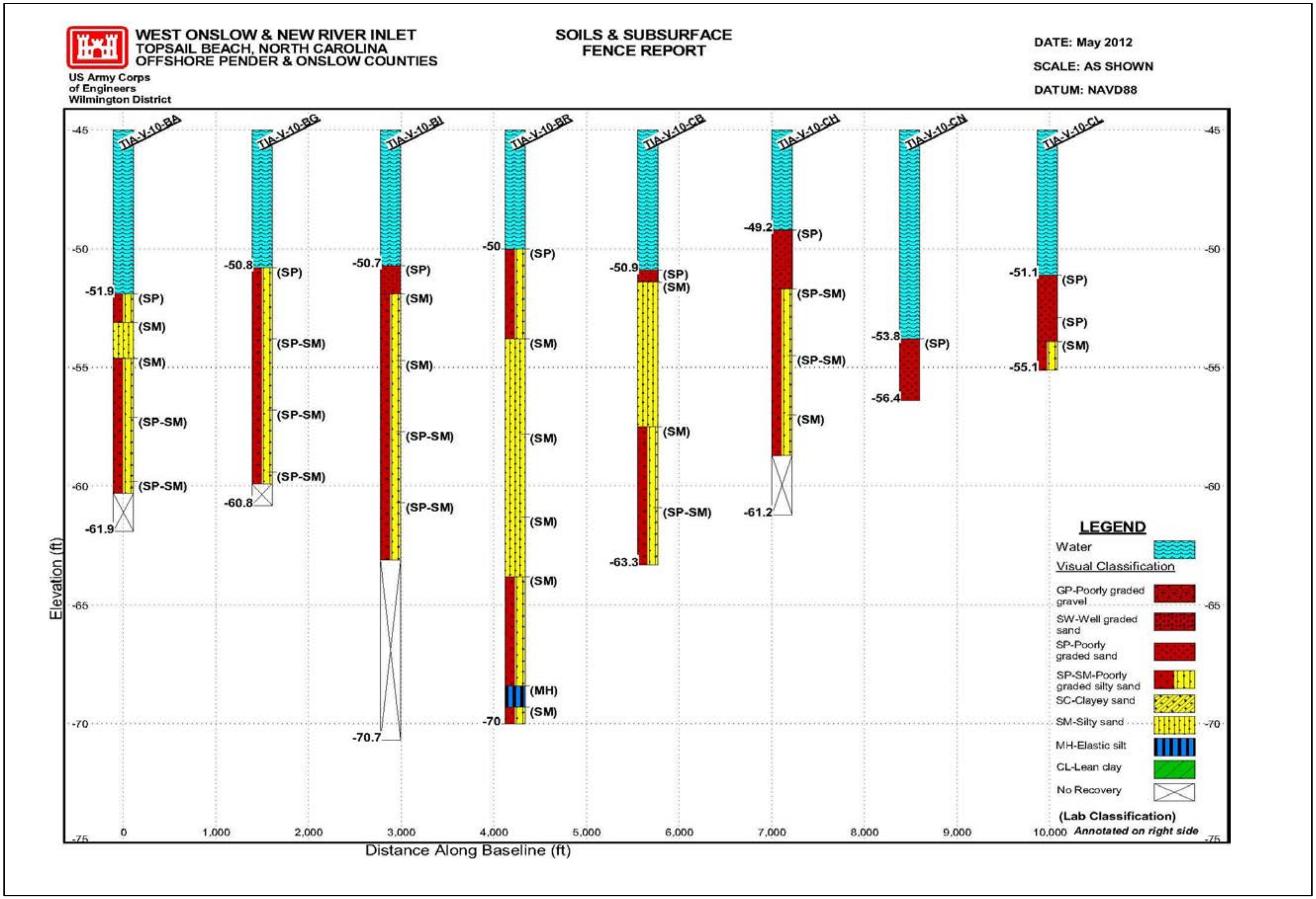


Figure 26. 2-D geologic cross section, profile H-H'.

H’

H

Figure 26. 2-D geologic cross section, profile H-H’.

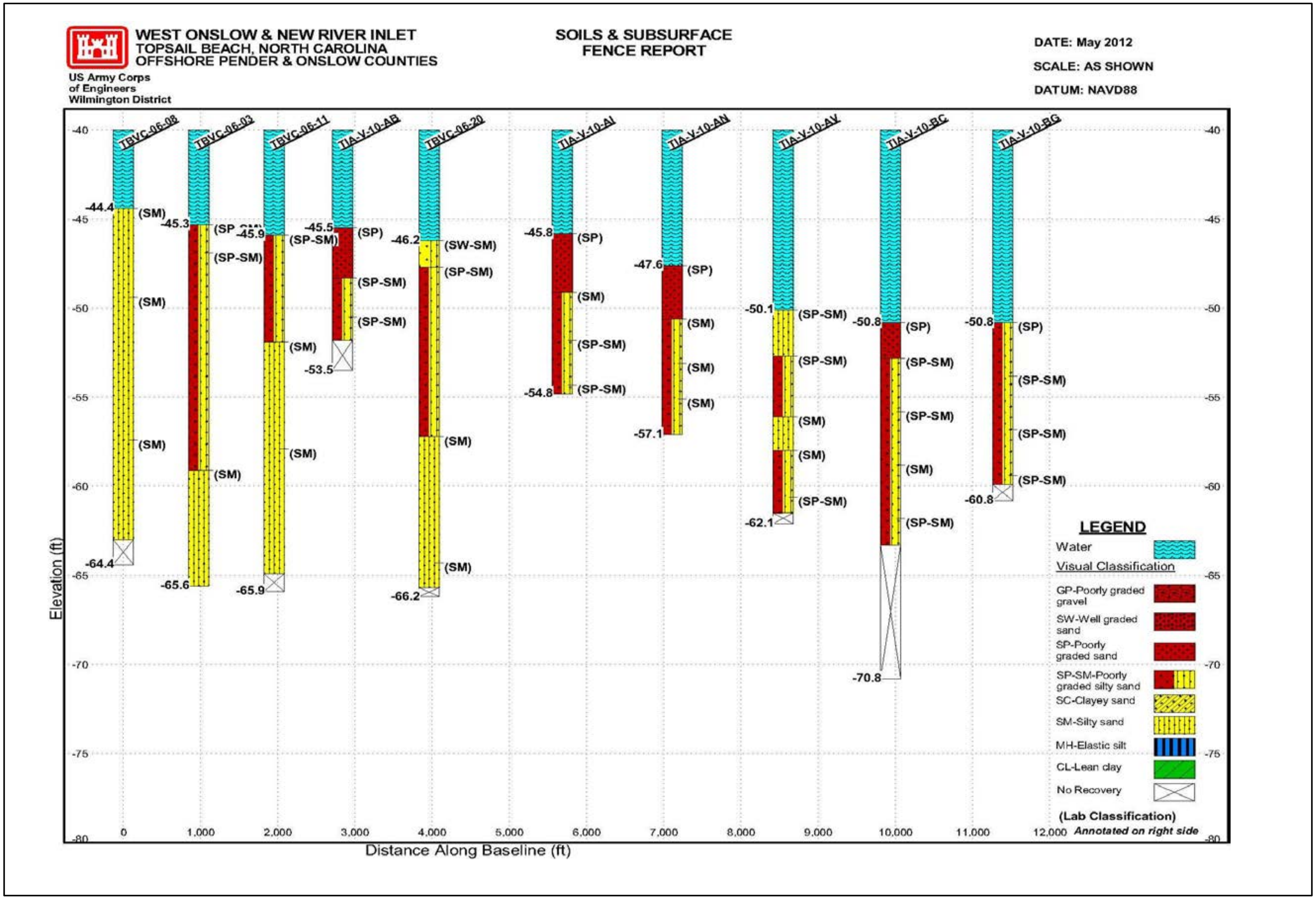


Figure 27. 2-D geologic cross section, profile I-I'.

I’

I

Figure 27. 2-D geologic cross section, profile I-I’.

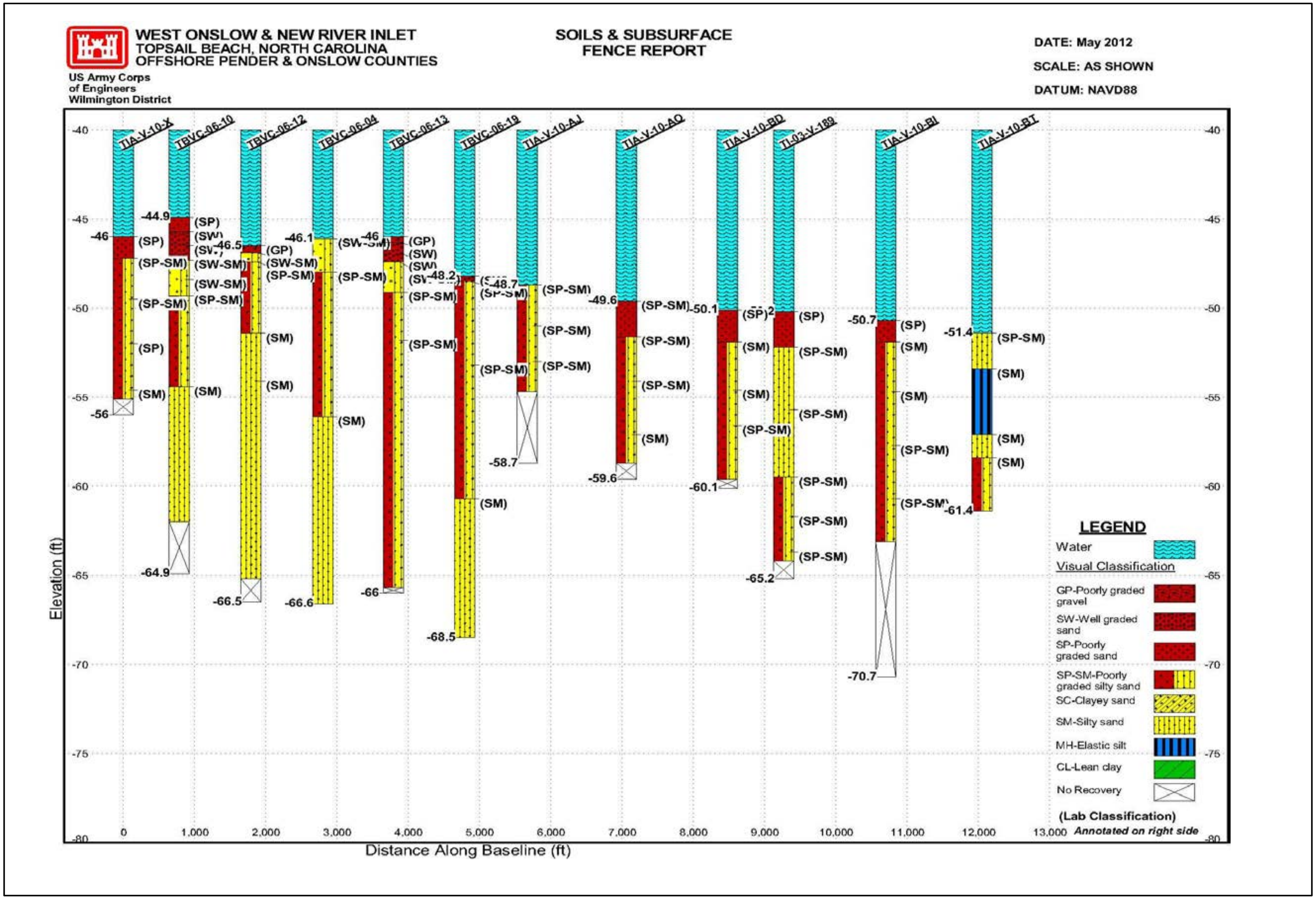


Figure 28. 2-D geologic cross section, profile J-J'.

J

J'

Figure 28. 2-D geologic cross section, profile J-J'.

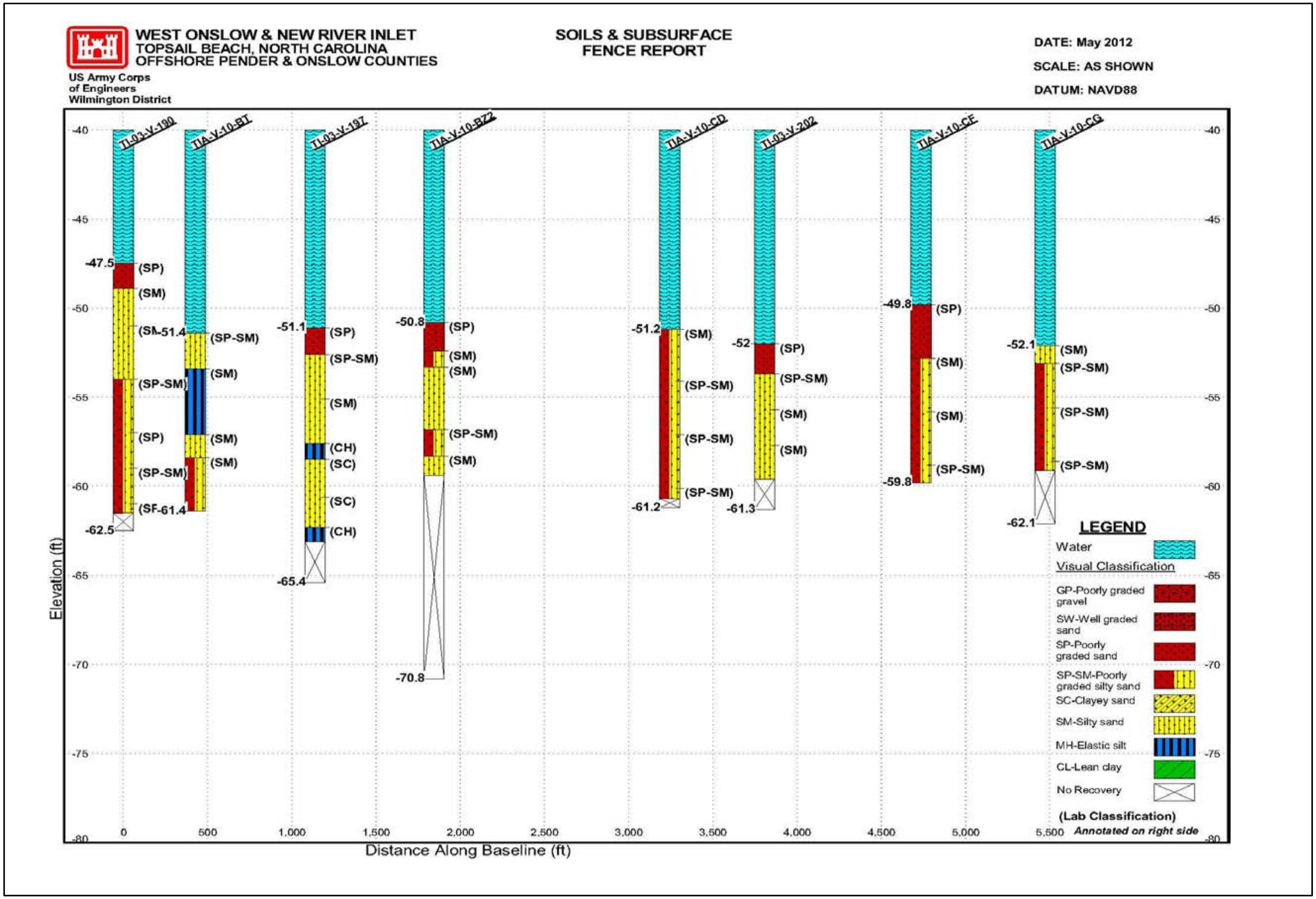


Figure 29. 2-D geologic cross section, profile K-K'.

K K’

Figure 29. 2-D geologic cross section, profile K-K’.

5.2 Compatibility Analysis

5.2.1 Borrow Site A Compatibility Data

The boring logs and particle size analysis for each vibracore within Borrow site A are available in Appendix A-1. A particle size analysis was performed for each sample documented on the boring logs. The particle/grain size characteristics of the samples were used to develop a weighted composite grain size distribution that is representative of the material in Borrow site A. To determine the composite characteristics for the borrow, first each core was weighted based upon the usable thickness of material in the core and then the sum weighted characteristics from the cores are divided by the total usable thickness in the borrow. Included in the analysis was an estimate of the amount of fine-grained sediments in each core that is finer than the 230 sieve (0.0625 millimeters). The Wilmington District standard with regard to the percentage of fine-grained sediments is that borrow areas containing more than 10 percent fines are generally considered to be incompatible for placement on the beach due to potential problems with increased turbidity and siltation during placement. The standard set by the State of North Carolina in 2007 for governing sediment compatibility for beach nourishment states that "the average percentage by weight of fine-grained sediment (less than 0.0625 millimeters) in each borrow site shall not exceed the average percentage by weight of fine-grained sediment of the recipient beach characterization plus five (5) percent" (15A NCAC 07H.0312).

Based on the federal and state standards for sediment finer than the 230 sieve, Borrow site A was evaluated for composite percent fines content of 6.0 percent [1] and under 10 percent fines. The final weighted composite characteristics for each boring within the borrow are given in Appendix A-2. In Appendix A-2, the tables are divided based on the composite percent fines content. Table 3 lists the composite mean, standard deviation, percent fines content, and percent shell content for the native beach and from Borrow site A.

Table 3. Mean sampling data from the native beach and Borrow site A.

		Borrow site A	
Data	**Native Beach**	**6.0% Fines**	**Under 10% Fines**
Mean (phi)	2.15	2.44	2.61
Std Dev (phi)	0.66	0.71	0.60
Weight % Fines Passing #230	1.0	5.9	7.5
Visual % Shell	11	8	6

In general, the material in Borrow site A is finer than the native beach. As shown in Table 3, when the percent fines content is increased, the mean phi value of the material in Borrow site A also is increased. As the phi value increases the mean grain size of the borrow material becomes finer. Table 3 also lists the composite visual estimation of the percent shell content. The

[1] This value is 5 percent plus the native beach 1.0 percent silt. The native beach value is assumed based on 13 samples. The calculated composite native beach values in this report meet the State of North Carolina standards.

composite percent shell content for Borrow site A is less than what is currently on the native beach. The NC standard for governing sediment compatibility for beach nourishment states that “the average percentage by weight of calcium carbonate of the recipient beach characterization plus 15 percent” is allowed (15A NCAC 07H.0312). The borrow clearly complies with the NC standard. There is also a statement in the standard about the maximum grain size allowed for beach fill projects. As stated before the grain size is general finer from the borrow, but there were a few samples that had large “gravel” (4.76 millimeters or greater) size grains. Generally, the samples with gravel size grains had a large percentage of shell. It is thought that the gravel size grains were actually shell, and as a result of the composite percent shell content, the material from these samples were included. The material from Borrow site A appears to be compatible to the native beach but the overfill ratio is needed to determine if the material is suitable for nourishing the beach and if there is enough material for the project.

5.2.1.1 Isopach Mapping of Borrow Site A

Figures 30-33 are isopach maps of Borrow site A. These figures visualize the usable thickness and the fines distribution of the beach fill material based on the composite percent fines content for 6.0 and approximately 7.5 percent fines. The isopach maps shown on Figures 30 and 32 displays from light (yellow) to dark (dark blue) the increasing of depths of usable beach fill material for approximately 7.5 and 6.0 percent fines, respectively. As the percent fines is decreased the usable beach fill material decreases, i.e., Figure 32, which has composite percent fines of 6.0 percent exhibits greater quantities of material with less than 4 feet of usable thickness than Figure 30.

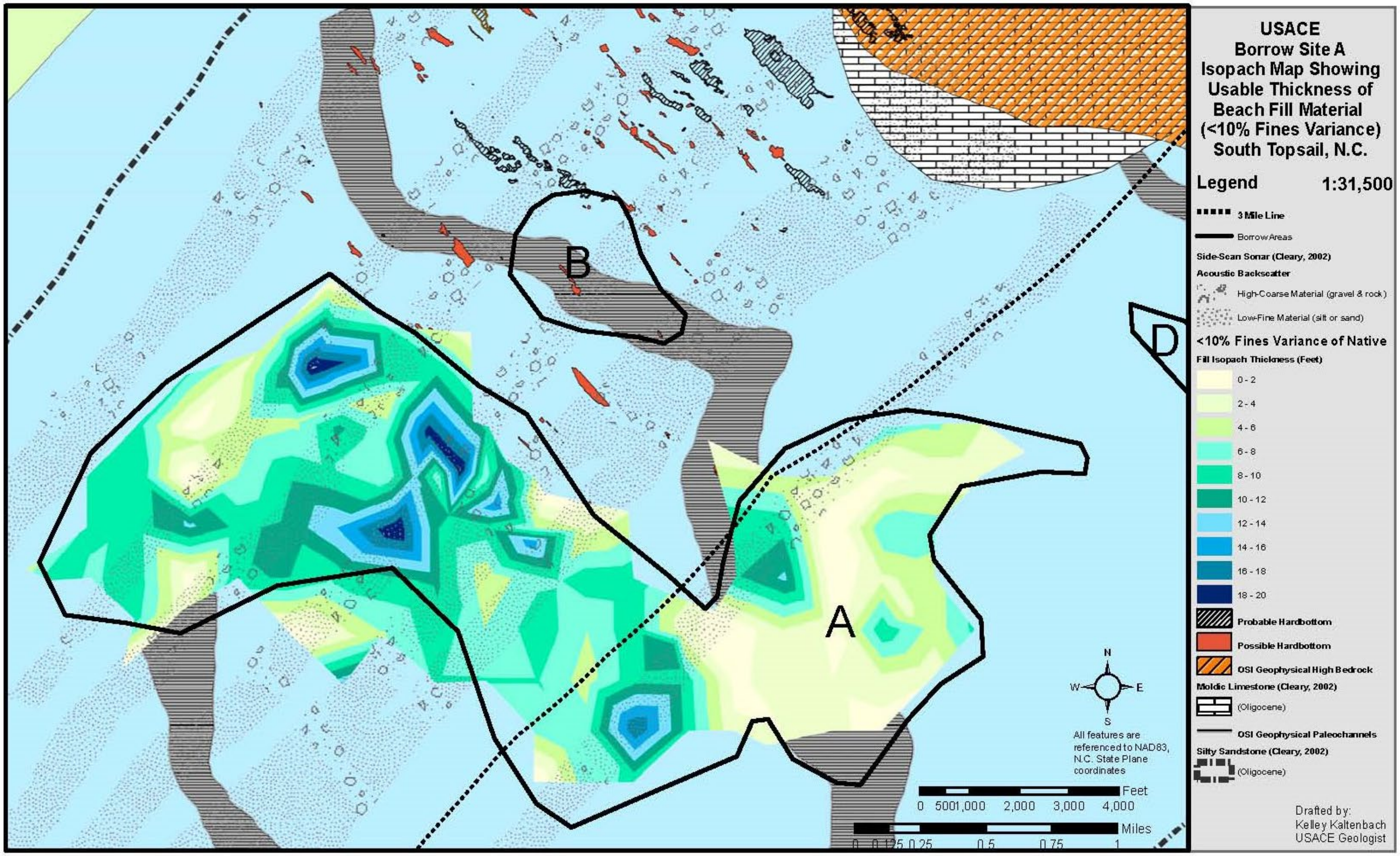


Figure 30. USACE Borrow site A isopach map showing usable thickness of beach fill material with a fines variance of less than 10 percent.

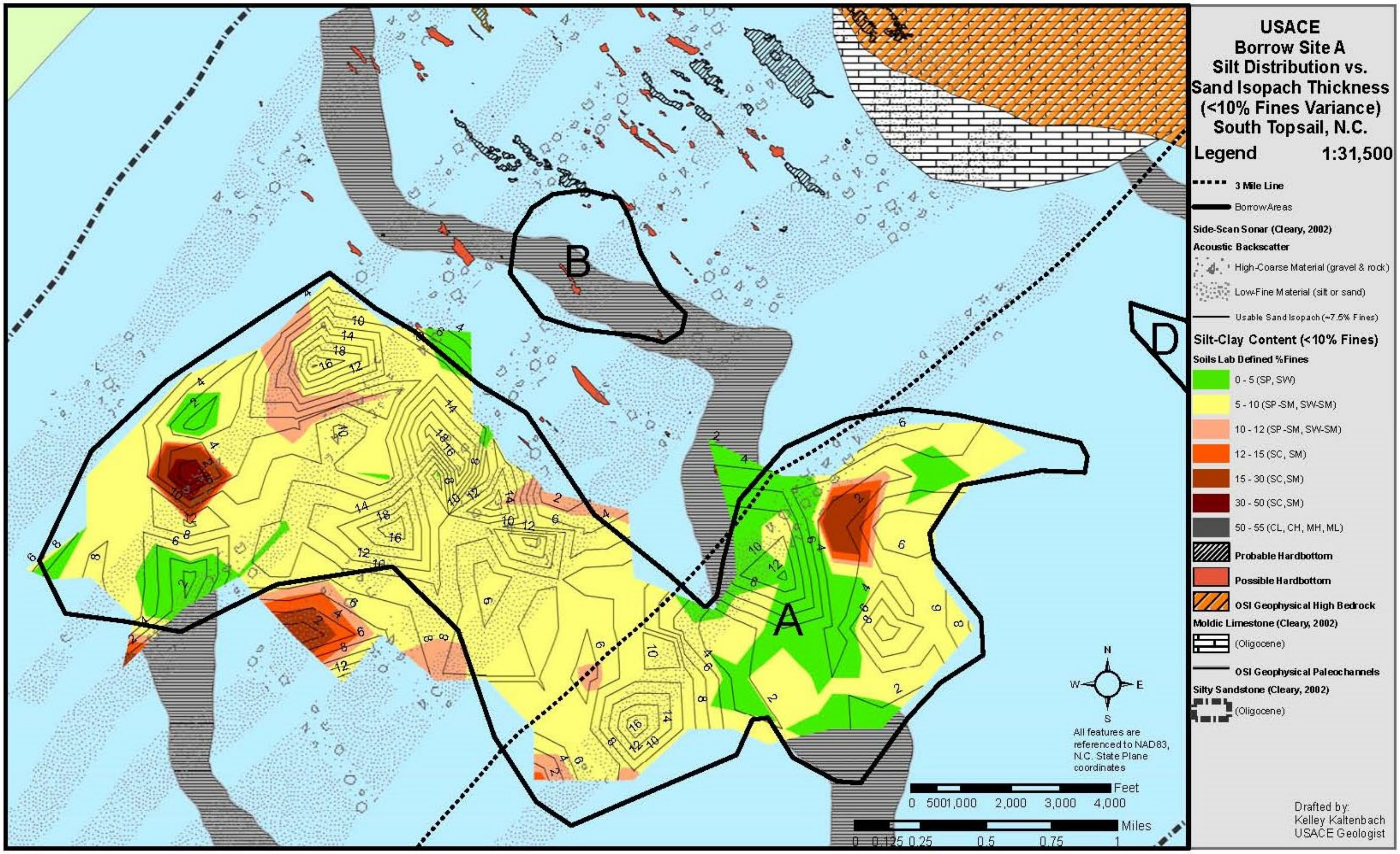


Figure 31. USACE Borrow site A fines distribution versus sand isopach thickness for a fines variance of less than 10 percent.

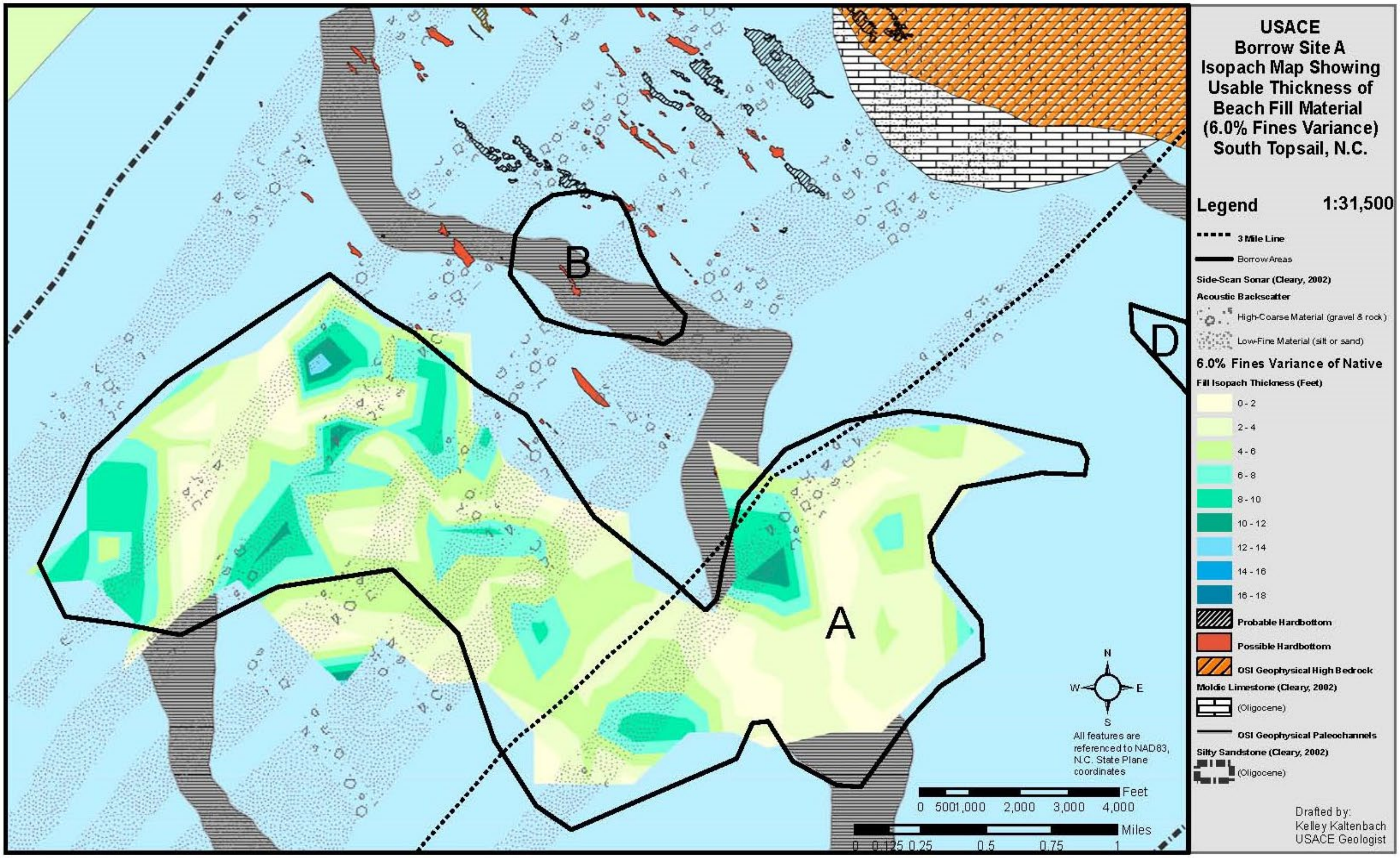


Figure 32. USACE Borrow site A isopach map showing usable thickness of beach fill material with a fines variance of less than 6 percent.

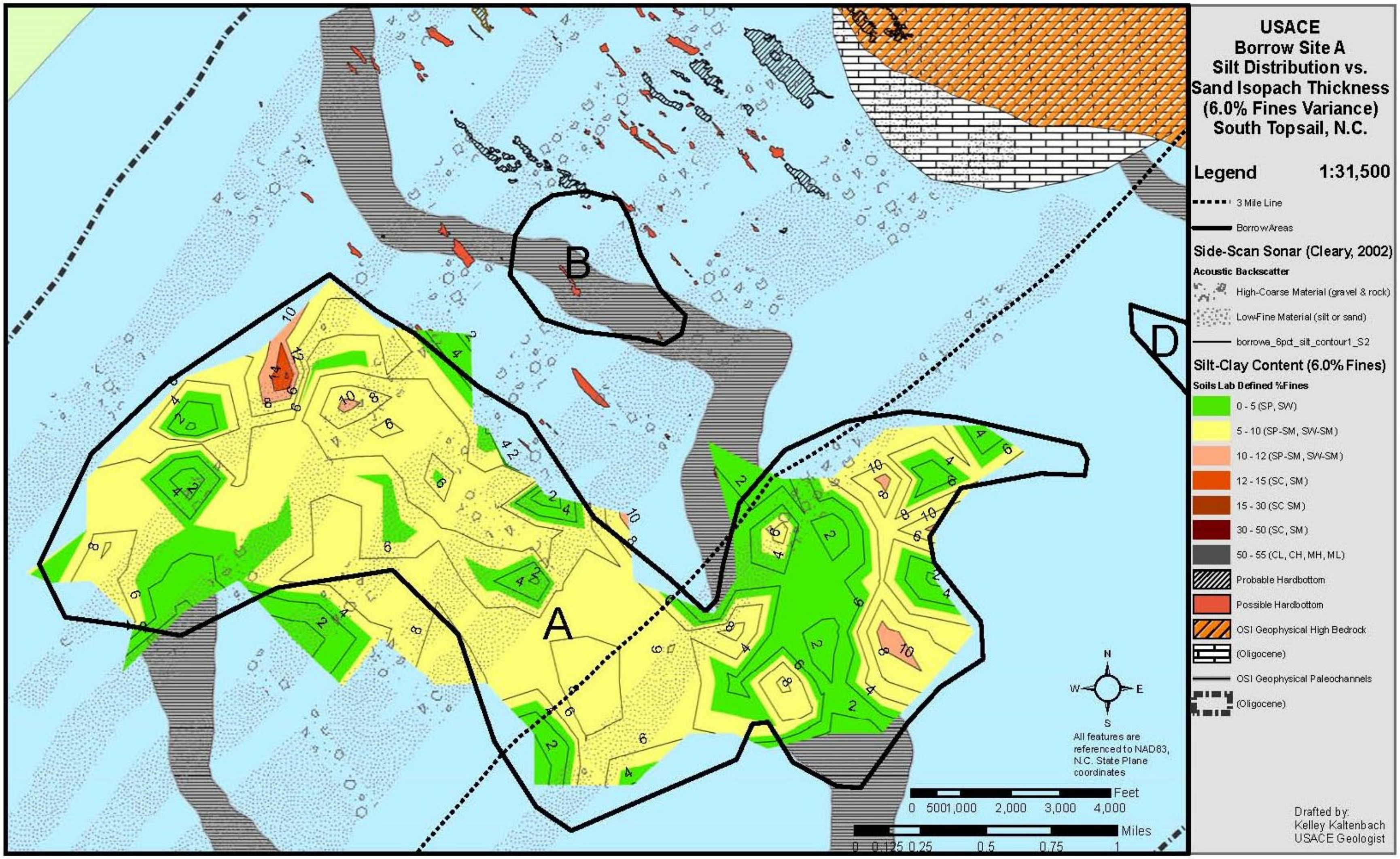


Figure 33. USACE Borrow site A fines distribution versus sand isopach thickness for a fines variance of less than 6 percent.

As shown in Figures 31 and 33, Borrow site A consists mostly of well to poorly graded sand with a fines content ranging from 5 to 12 percent. In general, this material is suitable beach fill material by the federal standards (percent fines content approximately 7.5 percent). Under the NC standard for beach fill material only the well/poorly graded sand and a limited amount of the well/poorly graded sand with silt is usable. The maps on Figures 31 and 33 show the well/poorly graded sand material in green. The green sections on these figures are very small sections within the borrow and are generally shallow in depth of usable material. Areas within Borrow site A that contain less than 2 feet of usable material are not expected to be dredged for this project.

5.2.2 Overfill Ratio

The suitability of the borrow material for beach placement is based upon the overfill ratio. The overfill ratio is computed by numerically comparing the size distribution characteristics of the native beach sand with that of the borrow site, including an adjustment for the percentage of fines within the borrow site. The overfill ratio is primarily based on the assumption that the borrow material will undergo mechanical sorting and winnowing once exposed to waves and currents in the littoral zone, with the resulting sorted distribution approaching that of the native sand. Since borrow material will rarely match the native material exactly, the amount of borrow material needed to result in a net cubic yard of beach fill material will generally be greater than one cubic yard. The excess material needed to yield one net cubic yard of material in place on the beach profile is the overfill ratio. The overfill ratio is defined as the ratio of the volume of borrow material needed to yield one net cubic yard of fill material. For example, if 1.5 cubic yards of fill material is needed to yield one net yard in place, the overfill factor would equal 1.5. A summary of the computed overfill ratios is shown in Table 4. Several numerical procedures were used to determine the overfill ratios for Borrow site A based on a percent fines content of 6.0 and approximately 7.5 percent).

The overfill ratio for Shore Protection Manual (SPM) method can be computed using the Automated Coastal Engineering System (ACES) produced by the U.S. Army Coastal Engineering Research Center. The procedure for the SPM method is also described in the U.S. Army Coastal Engineering Manual EM-1110-2-1100 Part V (July 2003). The SPM method has been determined to have problems correctly calculating overfill ratios when the standard deviation of the phi value is similar or less than the native beach standard deviation. As shown in Table 3 the standard deviation is less or very similar to the native beach standard deviation. Since the SPM method is inaccurate for determining the overfill ratio for Borrow site A three other methods were used. The Dean method (Dean, 1974) which is similar to the SPM method, as it uses the phi values, standard deviation, and a graph to determine the overfill ratio, determined that the overfill ratio for both 6.0 and approximately 7.5 percent fines content is 1.10. Since the differences between the overfill ratios determined using the SPM and Dean methods were large the Equilibrium Profile Method (EPM, Dean, 1991) and Equilibrium Slope Method (ESM, Pilarczyk, Overeem, and Bakker, 1986) were performed. Both the EPM and ESM produced overfill values that increased when the percent fines content increased and were under 1.5. The EPM will be used to determine the volume of sand need for the beach nourishment.

Table 4. Comparison of Borrow site A overfill ratios based on composite percent fines and method.

Composite Percent Fines	Overfill Ratio			
	Shore Protection Manual Method	Dean Method	Equilibrium Profile Method	Equilibrium Slope Method
6.0	1.63	1.10	1.21	1.35
~7.5	3.66	1.10	1.36	1.43

6.0 Summary

6.1 Initial Construction and Renourishment

Initial construction will require approximately 3,908,300 - 4,392,800 cubic yards of sand from Borrow site A depending on the overfill ratio (see Table 5). The material will be pumped to the beach by either a pipeline or hopper dredge or by a combination of pipeline and hopper dredges. After the material is on the beach it will then be shaped on the beach by earth moving equipment. The initial construction profile will extend seaward of the final design berm profile a variable distance to cover anticipated sand movement during and immediately following construction. This variable distance will generally range from 100 to 200 feet along the project depending upon foreshore slopes established by the fill material. Once sand redistribution along the foreshore occurs, the adjusted profile should resemble the design berm profile in Figure 34. Initial beach fill construction should take two, 5 month long dredging windows to complete. Periodic renourishment will require approximately 834,900 - 938,400 cubic yards of sand from the borrow areas depending on the overfill ratio at intervals of 4 years. Over the 50 year life of the project 13,927,100 - 15,653,600 cubic yards of sand will be placed on Topsail Beach. The volumes required are reported as borrow volumes including overfill ratios, not actual volume in place, which is equal to the volumes shown in Table 5 for the overfill ratio of 1.00.

Table 5. Nourishment quantities based on overfill ratios.

Overfill Ratio	Initial Construction (Cubic Yards)	Renourishment (Cubic Yards)	Total (Cubic Yards)
1.00	3,230,000	690,000	11,510,000
1.21	3,908,300	834,900	13,927,100
1.36	4,392,800	938,400	15,653,600

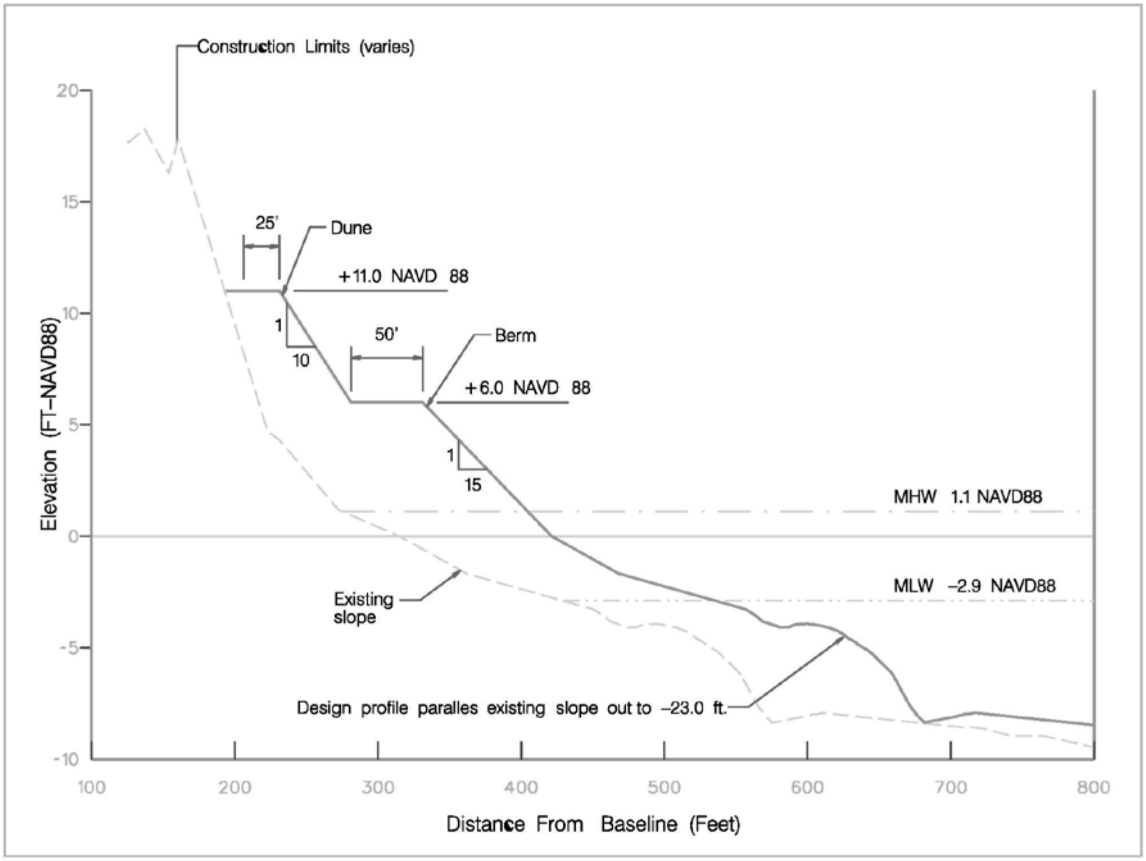


Figure 34. Locally Preferred Plan, Cross Section

In terms of available volumes, Table 6 lists the PED and Feasibility volumes of beach fill quality sand which can be expected from the borrow sites listed. Table 6 is inclusive of all borrow sites that may potentially be utilized for initial construction or renourishment of the project. It is expected that borrow site A will be sufficient to cover the needs of the project, but borrow sites B, C, and D are provided to supplement the project if needed. It is important to note that borrow sites B, C, and D are also supplemental to the Surf City and North Topsail Beach project, and if any of these borrow sites are needed an agreement would need to be made between the two projects. Also, borrow sites B, C, and D have only undergone a Feasibility level investigation, and determining more accurate volumes would be requires by means of more densely spaced vibracores. This additional investigation, along with further compatibility analysis and overfill ratio determination, would be required before either project can use borrow sites B, C, and D.

Table 6. Beach fill from available borrow sites.

Borrow Site	Available Volume (Cubic Yards)
A	14,444,000
B	820,000
C	2,570,000
D	1,860,000
Total	19,694,000

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Addendum A-1: Geotechnical Data

(Boring logs and laboratory data is available by request.)

Addendum A-2: Composite Borings Results

Composite results for 6.0 percent fines content

Table 7. Results from the 2003 USACE borings within Borrow site A.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TI-03-V-124	2.00	1.72	1.59	9.02	22	3.45	3.17
TI-03-V-125	2.00	2.31	0.98	8.36	17	4.62	1.95
TI-03-V-126	4.80	1.76	1.79	7.29	22	8.43	8.58
TI-03-V-127	4.50	2.09	1.22	5.13	16	9.38	5.49
TI-03-V-129	2.50	1.84	1.09	1.38	19	4.61	2.73
TI-03-V-130	8.30	2.71	0.42	5.26	3	22.52	3.46
TI-03-V-182	3.00	2.39	0.64	4.43	7	7.16	1.93
TI-03-V-187	4.00	2.63	0.56	6.05	9	10.51	2.23
TI-03-V-188	5.00	2.22	1.00	5.71	14	11.11	5.02
TI-03-V-189	5.50	2.24	0.85	5.88	13	12.32	4.67
TI-03-V-197	3.50	2.57	0.50	6.43	5	9.00	1.74
TI-03-V-202	3.00	2.38	0.74	6.46	9	7.14	2.21
TI-03-V-203	3.20	1.34	1.78	2.13	20	4.30	5.69
TI-03-V-208	3.00	2.69	0.43	6.26	5	8.06	1.30
TI-03-V-216	1.50	1.38	1.99	6.75	21	2.07	2.99
Totals	55.8	32.3	15.6	86.5	201.7	124.7	53.2

Borrow site A Composite Data	
Mean (phi)	**2.23**
Std Dev (phi)	**0.95**
Weight % fines passing #230	**5.7**
Visual % Shell	**12.2**

Table 8. Results from the 2006 CPE borings within Borrow site A.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TBVC-06-01	4.00	3.01	0.41	8.27	1	12.02	1.63
TBVC-06-02	4.20	0.49	2.29	6.19	50	2.07	9.63
TBVC-06-03	13.80	2.89	0.36	4.64	2	39.88	4.98
TBVC-06-04	10.00	2.89	0.40	7.25	4	28.89	3.99
TBVC-06-05	2.50	2.80	0.50	7.12	3	7.00	1.26
TBVC-06-06	2.00	1.60	2.22	6.63	23	3.21	4.44
TBVC-06-07	0.50	2.73	0.38	5.15	4	1.37	0.19
TBVC-06-08	1.00	2.96	0.43	11.36	1	2.96	0.43
TBVC-06-09	6.60	2.66	0.53	6.90	8	17.57	3.52
TBVC-06-10	9.50	2.59	0.72	4.41	8	24.65	6.82
TBVC-06-11	1.00	2.85	0.54	10.90	1	2.85	0.54
TBVC-06-12	1.00	1.47	2.38	7.96	47	1.47	2.38
TBVC-06-13	5.80	2.75	0.59	6.69	9	15.96	3.43
TBVC-06-14	3.50	2.38	0.97	5.69	14	8.33	3.38
TBVC-06-15	1.10	2.64	0.52	4.36	5	2.91	0.57
TBVC-06-16	7.30	2.93	0.42	6.42	1	21.36	3.04
TBVC-06-17	0.00	0.00	0.00	0.00	0	0.00	0.00
TBVC-06-18	2.20	0.05	3.11	1.65	49	0.11	6.85
TBVC-06-19	3.00	2.95	0.43	6.61	2	8.84	1.30
TBVC-06-20	3.00	2.90	0.42	7.08	1	8.71	1.27
Totals	82.0	45.6	17.6	125.3	232.1	210.2	59.7

Borrow site A Composite Data

Mean (phi)	**2.56**
Std Dev (phi)	**0.73**
Weight % fines passing #230	**6.1**
Visual % Shell	**9.0**

Table 9. Results from the 2010 USACE borings within Borrow site A.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TIA-V-10-A	7.3	2.78	0.37	6.32	4	20.27	2.72
TIA-V-10-B	9.5	2.77	0.41	5.61	4	26.30	3.88
TIA-V-10-C	8.5	2.80	0.30	4.99	3	23.81	2.58
TIA-V-10-D	7.6	2.73	0.43	7.59	3	20.74	3.30
TIA-V-10-E	9.2	2.64	0.41	4.88	4	24.25	3.74
TIA-V-10-F	8.9	2.72	0.42	5.99	3	24.20	3.73
TIA-V-10-G	9.3	2.74	0.46	5.01	8	25.46	4.24
TIA-V-10-H	5.0	1.79	1.67	7.43	21	8.94	8.34
TIA-V-10-I	0.0	0.00	0.00	0.00	0	0.00	0.00
TIA-V-10-J	0.5	2.52	0.48	4.90	6	1.26	0.24
TIA-V-10-K	1.0	2.46	0.56	3.00	7	2.46	0.56
TIA-V-10-L	9.8	2.72	0.35	4.87	3	26.67	3.40
TIA-V-10-M	6.5	2.26	0.90	5.11	13	14.67	5.87
TIA-V-10-N	3.2	2.59	0.53	6.18	7	8.29	1.70
TIA-V-10-O	3.3	2.67	0.44	6.20	5	8.80	1.46
TIA-V-10-P	2.7	2.57	0.49	6.80	8	6.94	1.31
TIA-V-10-Q	1.0	2.92	0.54	14.30	0	2.92	0.54
TIA-V-10-R	7.8	2.80	0.32	5.10	3	21.88	2.47
TIA-V-10-S	10.5	2.80	0.33	4.71	4	29.40	3.48
TIA-V-10-T	6.1	1.93	1.43	6.16	16	11.77	8.73
TIA-V-10-U	2.0	1.67	1.79	7.18	20	3.35	3.58
TIA-V-10-V	12.1	2.75	0.43	7.86	3	33.26	5.26
TIA-V-10-W	9.0	2.61	0.49	6.78	7	23.45	4.37
TIA-V-10-X	8.6	2.63	0.50	6.53	9	22.59	4.32
TIA-V-10-Y	5.0	2.38	0.68	6.50	11	11.90	3.40
TIA-V-10-Z	5.5	2.09	1.16	5.96	16	11.48	6.36
TIA-V-10-AA	9.7	2.59	0.44	5.52	6	25.08	4.28
TIA-V-10-AB	6.3	2.58	0.46	5.10	4	16.28	2.89
TIA-V-10-AC	9.2	2.39	0.70	3.72	11	21.97	6.40
TIA-V-10-AD	3.0	2.32	0.81	6.79	14	6.96	2.44
TIA-V-10-AE	6.2	2.46	0.68	6.39	10	15.26	4.23
TIA-V-10-AF	6.2	2.45	0.54	4.38	8	15.22	3.35
TIA-V-10-AG	6.7	2.62	0.40	4.71	3	17.55	2.69
TIA-V-10-AH	8.0	2.68	0.41	5.63	3	21.42	3.28
TIA-V-10-AI	8.5	2.17	0.99	6.71	14	18.48	8.39
TIA-V-10-AJ	6.0	2.64	0.50	6.84	6	15.81	2.99
TIA-V-10-AK	2.0	1.94	1.24	5.28	17	3.88	2.48
TIA-V-10-AL	6.0	2.50	0.75	7.70	11	15.01	4.49
TIA-V-10-AM	3.8	2.32	0.76	4.39	9	8.82	2.89
TIA-V-10-AN	3.0	2.30	0.66	1.50	8	6.90	1.97
TIA-V-10-AO	4.0	2.58	0.47	7.25	7	10.32	1.89
TIA-V-10-AP	5.0	2.67	0.39	6.28	4	13.36	1.97
TIA-V-10-AQ	3.0	1.92	1.39	7.37	17	5.75	4.17

continued							
Boring Number	**Thickness (ft)**	**Mean (phi)**	**Std Dev (phi)**	**Weight % fines (passing #230)**	**Visual % Shell**	**Weighted Mean**	**Weighted Std Dev**
TIA-V-10-AR	8.8	2.80	0.28	7.50	1	24.64	2.44
TIA-V-10-AS	4.0	2.70	0.35	8.04	1	10.79	1.40
TIA-V-10-AT	2.1	2.35	0.54	2.00	6	4.94	1.14
TIA-V-10-AU	6.0	2.51	0.48	6.53	10	15.07	2.87
TIA-V-10-AV	4.5	2.63	0.47	7.87	6	11.85	2.10
TIA-V-10-AW	3.0	2.63	0.58	9.85	8	7.90	1.75
TIA-V-10-AX	5.0	2.62	0.40	8.11	3	13.10	1.98
TIA-V-10-AY	0.0	0.00	0.00	0.00	0	0.00	0.00
TIA-V-10-AZ	4.0	2.70	0.58	7.33	4	10.79	2.30
TIA-V-10-BA	1.2	2.32	0.68	3.90	6	2.78	0.82
TIA-V-10-BB	9.8	2.73	0.43	7.35	4	26.73	4.24
TIA-V-10-BC	5.0	2.61	0.47	7.08	4	13.06	2.37
TIA-V-10-BD	3.0	1.25	2.17	7.18	23	3.75	6.51
TIA-V-10-BE	2.5	1.52	1.73	6.30	23	3.81	4.33
TIA-V-10-BF	5.0	2.60	0.48	7.20	3	13.02	2.40
TIA-V-10-BG	9.1	2.63	0.39	6.26	2	23.94	3.57
TIA-V-10-BH	2.5	0.82	2.79	5.82	10	2.05	6.98
TIA-V-10-BI	1.2	1.62	1.68	3.50	18	1.94	2.01
TIA-V-10-BJ	0.6	2.01	1.55	9.00	18	1.20	0.93
TIA-V-10-BK	9.8	2.49	0.44	2.56	5	24.36	4.29
TIA-V-10-BL	10.0	2.45	0.54	2.46	6	24.46	5.37
TIA-V-10-BM	9.5	2.65	0.56	6.89	10	25.22	5.35
TIA-V-10-BN	4.4	1.38	1.18	1.26	20	6.06	5.20
TIA-V-10-BO	3.5	2.44	0.56	6.41	7	8.52	1.98
TIA-V-10-BP	0.0	0.00	0.00	0.00	0	0.00	0.00
TIA-V-10-BQ	11.0	2.34	0.74	3.52	8	25.72	8.12
TIA-V-10-BR	3.8	1.46	1.68	2.30	20	5.56	6.40
TIA-V-10-BS	2.0	2.74	0.62	8.70	7	5.47	1.24
TIA-V-10-BT	2.0	2.54	0.47	5.20	3	5.08	0.94
TIA-V-10-BU	2.6	1.99	0.86	1.60	13	5.18	2.23
TIA-V-10-BW	1.0	1.79	0.80	1.80	8	1.79	0.80
TIA-V-10-BX	2.0	1.24	2.17	9.70	36	2.47	4.34
TIA-V-10-BY	3.5	1.53	1.77	7.70	23	5.36	6.20
TIA-V-10-BZ	2.0	2.25	0.61	1.80	3	4.51	1.22
TIA-V-10-BZ2	1.6	2.14	0.70	2.60	6	3.42	1.13
TIA-V-10-CA	1.5	2.15	0.67	1.50	7	3.23	1.00
TIA-V-10-CB	0.5	-0.05	3.28	3.30	47	-0.02	1.64
TIA-V-10-CC	3.6	1.43	1.97	6.19	25	5.13	7.11
TIA-V-10-CD	4.5	2.41	1.00	11.14	12	10.84	4.52
TIA-V-10-CE	3.0	1.78	1.44	7.49	20	5.35	4.31
TIA-V-10-CF	3.0	1.89	0.67	1.20	5	5.68	2.02
TIA-V-10-CG	3.0	2.32	1.11	10.77	12	6.97	3.32
TIA-V-10-CH	7.8	2.34	0.73	7.03	7	18.25	5.67
TIA-V-10-CI	1.2	2.80	0.45	11.00	7	3.36	0.54

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TIA-V-10-CJ	5.0	2.40	0.86	7.84	11	11.99	4.31
							continued
TIA-V-10-CK	6.5	1.20	2.52	7.00	19	7.81	16.38
TIA-V-10-CL	2.8	2.32	0.54	1.96	6	6.50	1.52
TIA-V-10-CM	2.4	2.56	0.44	5.70	3	6.13	1.06
TIA-V-10-CN	2.6	2.53	0.44	2.30	5	6.57	1.16
TIA-V-10-CO	3.3	2.57	0.45	6.28	3	8.47	1.49
TIA-V-10-CP	1.0	0.15	2.25	1.50	46	0.15	2.25
TIA-V-10-CQ	6.0	2.76	0.39	7.05	3	16.53	2.36
TIA-V-10-CR	9.5	2.72	0.37	4.33	4	25.81	3.55
TIA-V-10-CS	8.8	2.72	0.43	6.09	3	23.91	3.83
TIA-V-10-CT	8.5	2.10	1.00	6.64	14	17.88	8.50
Totals	487.0	218.0	78.3	553.1	920.7	1188.2	331.9

Borrow site A Composite Data

Mean (phi)	**2.44**
Std Dev (phi)	**0.68**
Weight % fines passing #230	**5.9**
Visual % Shell	**7.8**

Composite results for ~7.5 percent fines content

Table 10. Results from the 2003 USACE borings within Borrow site A.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TI-03-V-124	2.0	1.72	1.59	9.02	22	3.45	3.17
TI-03-V-125	4.1	2.62	0.60	9.87	13	10.76	2.47
TI-03-V-126	5.8	1.93	1.66	8.60	19	11.21	9.61
TI-03-V-127	4.9	2.19	1.11	5.22	15	10.74	5.42
TI-03-V-129	2.5	1.84	1.09	1.38	19	4.61	2.73
TI-03-V-130	8.3	2.71	0.42	5.26	3	22.52	3.46
TI-03-V-182	7.6	2.72	0.49	8.29	3	20.71	3.75
TI-03-V-187	11.5	2.82	0.47	8.33	4	32.39	5.44
TI-03-V-188	7.8	2.69	0.65	7.87	9	21.01	5.05
TI-03-V-189	11.5	2.56	0.72	8.65	10	29.48	8.24
TI-03-V-197	4.0	2.61	0.51	6.89	5	10.43	2.03
TI-03-V-202	3.7	2.44	0.77	7.62	9	9.02	2.85
TI-03-V-203	3.2	1.34	1.78	2.13	20	4.30	5.69
TI-03-V-208	3.2	2.70	0.44	6.47	5	8.63	1.39
TI-03-V-216	2.1	1.45	1.95	8.33	20	3.05	4.09
Totals	82.2	34.4	14.2	103.9	174.4	202.3	65.4

Borrow site A Composite Data

Mean (phi)	**2.46**
Std Dev (phi)	**0.80**
Weight % fines passing #230	**7.3**
Visual % Shell	**9.4**

Table 11. Results from the 2006 CPE borings within Borrow site A.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TBVC-06-01	8.0	2.93	0.46	9.05	1	23.42	3.71
TBVC-06-02	4.2	0.49	2.29	6.19	50	2.07	9.63
TBVC-06-03	20.3	2.91	0.40	7.56	2	59.14	8.13
TBVC-06-04	19.0	2.92	0.42	9.90	3	55.41	8.01
TBVC-06-05	10.0	2.93	0.43	10.00	1	29.27	4.31
TBVC-06-06	6.5	2.77	0.62	9.94	9	18.03	4.03
TBVC-06-07	3.5	2.93	0.45	11.92	1	10.24	1.59
TBVC-06-08	5.0	2.96	0.43	11.36	1	14.82	2.16
TBVC-06-09	10.9	2.75	0.57	9.43	5	29.97	6.19
TBVC-06-10	17.1	2.81	0.54	8.03	5	48.03	9.23
TBVC-06-11	6.0	2.85	0.54	10.90	1	17.09	3.26
TBVC-06-12	4.9	2.95	0.46	9.98	10	14.46	2.23
TBVC-06-13	19.7	2.92	0.44	7.27	3	57.46	8.66
TBVC-06-14	10.6	2.83	0.53	8.31	6	30.03	5.61
TBVC-06-15	19.9	2.96	0.45	9.49	1	58.86	8.93
TBVC-06-16	15.3	2.96	0.42	7.13	1	45.27	6.45
TBVC-06-17	0.3	2.96	0.49	11.90	1	0.89	0.15
TBVC-06-18	9.3	2.70	0.63	7.49	13	25.08	5.86
TBVC-06-19	15.5	2.95	0.46	9.86	1	45.73	7.15
TBVC-06-20	12.5	2.91	0.44	9.79	1	36.41	5.47
Totals	218.5	55.4	11.5	185.5	117.6	621.7	110.8

Borrow site A Composite Data

Mean (phi)	**2.85**
Std Dev (phi)	**0.51**
Weight % fines passing #230	**8.9**
Visual % Shell	**4.2**

Table 12. Results from the 2010 USACE borings within Borrow site A.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TIA-V-10-A	8.3	2.79	0.39	7.10	4	23.16	3.24
TIA-V-10-B	9.5	2.77	0.41	5.61	4	26.30	3.88
TIA-V-10-C	8.5	2.80	0.30	4.99	3	23.81	2.58
TIA-V-10-D	7.6	2.73	0.43	7.59	3	20.74	3.30
TIA-V-10-E	9.2	2.64	0.41	4.88	4	24.25	3.74
TIA-V-10-F	8.9	2.72	0.42	5.99	3	24.20	3.73
TIA-V-10-G	9.3	2.74	0.46	5.01	8	25.46	4.24
TIA-V-10-H	8.9	2.30	1.05	9.10	13	20.51	9.31
TIA-V-10-I	0.0	0.00	0.00	0.00	0	0.00	0.00
TIA-V-10-J	12.4	2.78	0.50	9.45	4	34.50	6.18
TIA-V-10-K	1.0	2.46	0.56	3.00	7	2.46	0.56
TIA-V-10-L	9.8	2.72	0.35	4.87	3	26.67	3.40
TIA-V-10-M	9.5	2.37	0.86	7.25	9	22.51	8.14
TIA-V-10-N	6.0	2.72	0.46	7.16	5	16.34	2.76
TIA-V-10-O	4.8	2.71	0.48	8.29	4	13.03	2.31
TIA-V-10-P	2.7	2.57	0.49	6.80	8	6.94	1.31
TIA-V-10-Q	11.8	2.90	0.42	11.66	0	34.18	4.97
TIA-V-10-R	9.8	2.81	0.37	7.22	3	27.56	3.61
TIA-V-10-S	10.5	2.80	0.33	4.71	4	29.40	3.48
TIA-V-10-T	10.1	2.58	0.65	7.63	10	26.10	6.57
TIA-V-10-U	14.0	2.79	0.48	9.65	6	39.11	6.73
TIA-V-10-V	10.6	2.73	0.43	7.18	3	28.90	4.53
TIA-V-10-W	14.2	2.69	0.47	8.80	4	38.23	6.70
TIA-V-10-X	9.1	2.65	0.50	6.78	9	24.08	4.56
TIA-V-10-Y	8.0	2.58	0.49	8.15	7	20.67	3.93
TIA-V-10-Z	9.3	2.55	0.48	8.10	9	23.75	4.48
TIA-V-10-AA	9.7	2.59	0.44	5.52	6	25.08	4.28
TIA-V-10-AB	6.3	2.58	0.46	5.10	4	16.28	2.89
TIA-V-10-AC	9.2	2.39	0.70	3.72	11	21.97	6.40
TIA-V-10-AD	5.7	2.63	0.62	9.96	10	15.01	3.55
TIA-V-10-AE	6.7	2.55	0.57	6.56	9	17.11	3.83
TIA-V-10-AF	6.7	2.51	0.49	4.69	7	16.80	3.27
TIA-V-10-AG	6.7	2.62	0.40	4.71	3	17.55	2.69
TIA-V-10-AH	10.0	2.73	0.38	6.27	2	27.31	3.82
TIA-V-10-AI	9.0	2.23	0.92	6.74	13	20.11	8.25
TIA-V-10-AJ	6.0	2.64	0.50	6.84	6	15.81	2.99
TIA-V-10-AK	3.4	2.02	1.38	9.04	18	6.85	4.69
TIA-V-10-AL	10.3	2.71	0.52	7.82	6	27.95	5.35
TIA-V-10-AM	4.5	2.44	0.64	5.60	8	10.98	2.87
TIA-V-10-AN	7.5	2.58	0.49	8.78	6	19.34	3.70
TIA-V-10-AO	9.1	2.73	0.51	9.37	5	24.87	4.67
TIA-V-10-AP	9.5	2.80	0.42	7.85	4	26.59	3.97
TIA-V-10-AQ	6.0	2.60	0.59	9.17	10	15.62	3.54

							continued
Boring Number	**Thickness (ft)**	**Mean (phi)**	**Std Dev (phi)**	**Weight % fines (passing #230)**	**Visual % Shell**	**Weighted Mean**	**Weighted Std Dev**
TIA-V-10-AR	9.3	2.81	0.29	7.67	1	26.13	2.67
TIA-V-10-AS	8.1	2.81	0.32	8.89	1	22.78	2.62
TIA-V-10-AT	6.3	2.61	0.42	7.35	3	16.45	2.62
TIA-V-10-AU	8.1	2.58	0.45	7.20	8	20.92	3.62
TIA-V-10-AV	6.0	2.72	0.42	8.48	4	16.32	2.50
TIA-V-10-AW	5.0	2.67	0.60	10.59	8	13.37	2.99
TIA-V-10-AX	7.0	2.70	0.39	8.36	2	18.89	2.76
TIA-V-10-AY	0.0	0.00	0.00	0.00	0	0.00	0.00
TIA-V-10-AZ	7.2	2.77	0.55	9.22	2	19.93	3.98
TIA-V-10-BA	8.4	2.78	0.59	10.52	4	23.39	4.93
TIA-V-10-BB	18.0	2.85	0.37	8.12	2	51.24	6.70
TIA-V-10-BC	9.5	2.74	0.46	8.76	4	25.98	4.36
TIA-V-10-BD	9.5	2.19	1.27	8.70	11	20.85	12.10
TIA-V-10-BE	2.5	1.52	1.73	6.30	23	3.81	4.33
TIA-V-10-BF	9.3	2.74	0.49	9.13	3	25.52	4.58
TIA-V-10-BG	9.1	2.63	0.39	6.26	2	23.94	3.57
TIA-V-10-BH	2.5	0.82	2.79	5.82	10	2.05	6.98
TIA-V-10-BI	1.2	1.62	1.68	3.50	18	1.94	2.01
TIA-V-10-BJ	0.6	2.01	1.55	9.00	18	1.20	0.93
TIA-V-10-BK	9.8	2.49	0.44	2.56	5	24.36	4.29
TIA-V-10-BL	10.0	2.45	0.54	2.46	6	24.46	5.37
TIA-V-10-BM	9.5	2.65	0.56	6.89	9	25.22	5.35
TIA-V-10-BN	4.4	1.38	1.18	1.26	20	6.06	5.20
TIA-V-10-BO	4.1	2.45	0.58	7.48	7	10.04	2.37
TIA-V-10-BP	0.0	0.00	0.00	0.00	0	0.00	0.00
TIA-V-10-BQ	12.4	2.40	0.71	4.46	7	29.79	8.75
TIA-V-10-BR	3.8	1.46	1.68	2.30	20	5.56	6.40
TIA-V-10-BS	4.0	2.81	0.56	9.70	5	11.26	2.26
TIA-V-10-BT	2.0	2.54	0.47	5.20	3	5.08	0.94
TIA-V-10-BU	2.6	1.99	0.86	1.60	13	5.18	2.23
TIA-V-10-BW	1.0	1.79	0.80	1.80	8	1.79	0.80
TIA-V-10-BX	2.2	1.24	2.17	9.70	36	2.72	4.77
TIA-V-10-BY	3.4	1.55	1.75	7.58	23	5.26	5.95
TIA-V-10-BZ	2.0	2.25	0.61	1.80	3	4.51	1.22
TIA-V-10-BZ2	2.5	2.40	0.74	6.49	5	5.99	1.84
TIA-V-10-CA	1.5	2.15	0.67	1.50	7	3.23	1.00
TIA-V-10-CB	0.5	-0.05	3.28	3.30	47	-0.02	1.64
TIA-V-10-CC	3.6	1.43	1.97	6.19	25	5.13	7.11
TIA-V-10-CD	9.5	2.73	0.56	9.74	8	25.94	5.35
TIA-V-10-CE	5.0	1.85	1.49	9.40	21	9.23	7.46
TIA-V-10-CF	5.0	1.92	1.00	5.92	11	9.59	5.02
TIA-V-10-CG	7.0	2.84	0.37	10.39	5	19.89	2.57
TIA-V-10-CH	7.8	2.34	0.73	7.03	7	18.25	5.67
TIA-V-10-CI	1.2	2.80	0.45	11.00	7	3.36	0.54

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % fines (passing #230)	Visual % Shell	Weighted Mean	Weighted Std Dev
TIA-V-10-CJ	8.0	2.53	0.83	9.74	10	20.20	6.63
							continued
TIA-V-10-CK	6.5	1.20	2.52	7.00	19	7.81	16.38
TIA-V-10-CL	4.0	2.37	0.47	5.31	4	9.50	1.88
TIA-V-10-CM	2.4	2.56	0.44	5.70	3	6.13	1.06
TIA-V-10-CN	2.6	2.53	0.44	2.30	5	6.57	1.16
TIA-V-10-CO	3.3	2.57	0.45	6.28	3	8.47	1.49
TIA-V-10-CP	1.0	0.15	2.25	1.50	46	0.15	2.25
TIA-V-10-CQ	9.0	2.83	0.41	8.20	2	25.49	3.70
TIA-V-10-CR	9.5	2.72	0.37	4.33	4	25.81	3.55
TIA-V-10-CS	8.8	2.72	0.43	6.09	3	23.91	3.83
TIA-V-10-CT	8.5	2.10	1.00	6.64	14	17.88	8.50
Totals	656.1	228.0	70.8	637.4	807.7	1676.6	397.8

Borrow site A Composite Data	
Mean (phi)	**2.56**
Std Dev (phi)	**0.61**
Weight % fines passing #230	**7.1**
Visual % Shell	**6.5**

Addendum A-3: Project Update 2020

Borrow Areas A, B, C, and D, immediately southwest of Borrow Area E, were originally investigated as part of the West Onslow Beach CSDR project, a portion of which was intended to be supplemental to the Surf City & North Topsail Beach CSDR project (. The West Onslow Beach CSDR Project reached PED Phase I in 2010, at which time Borrow Area A was evaluated for design level volumes. However, since that time the local authority has worked to procure the sand needed for beach nourishment from New Topsail Inlet and other inland sources allowing for utilization of these borrow areas as part of the Surf City & North Topsail Beach CSRM Project. A detailed analysis of Borrow Area A compatibility and volumes is included in the West Onslow Beach CSDR Geotechnical Appendix which is available upon request. Borrow Areas B, C, and D have only undergone a feasibility level investigation, and determining more accurate volumes would be required by means of 1,000 feet grid spacing subsurface investigation and compatibility analysis.

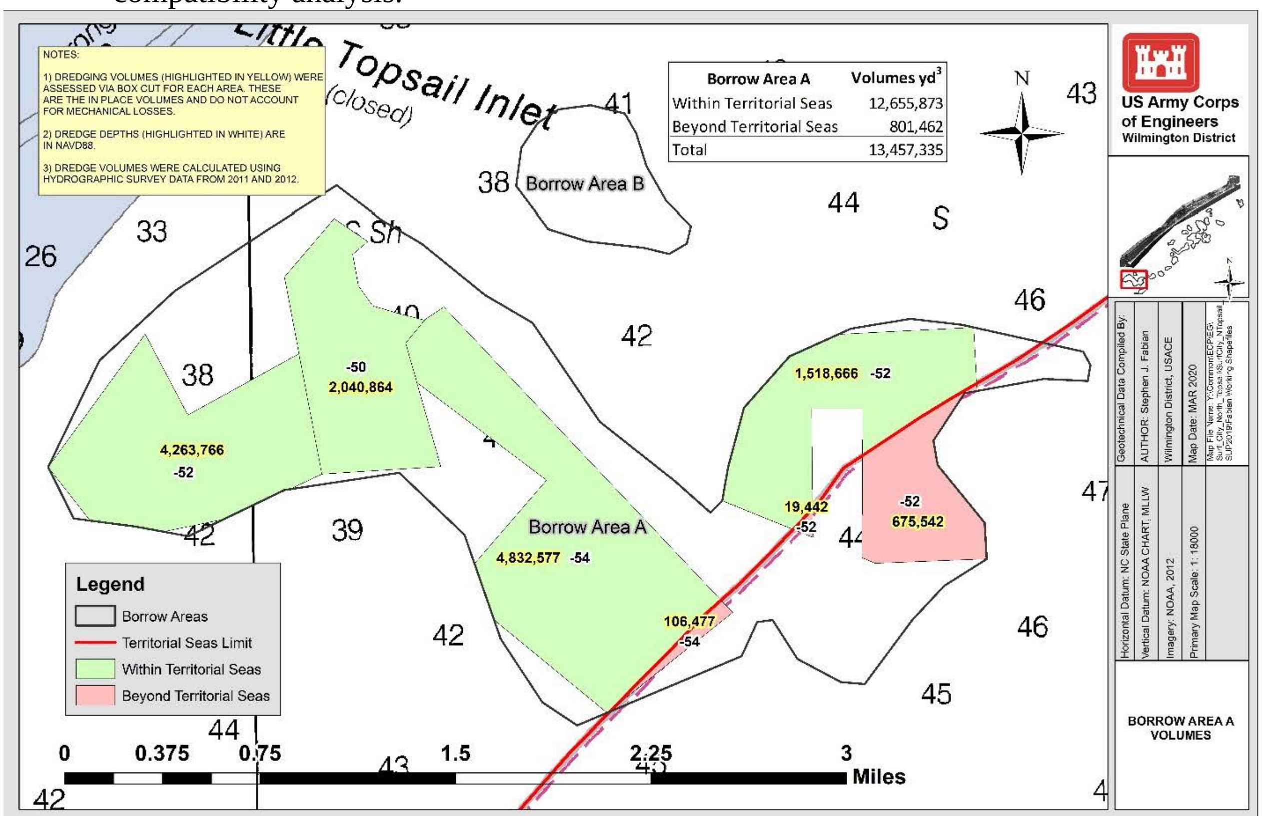


Figure 35. Borrow Area A dredge cut boxes and available volumes within and beyond the territorial sea limit (3 nautical mile line).

Addendum A-4: Project and Analysis Update 2021- 2024

In 2020, work began to complete the construction phase of the Surf City and North Topsail Beach CSRM project using Disaster Relief Act of 2019 (DRA 2019) construction funding. In 2021, North Topsail Beach opted out of the Federal project and chose not to sign the Project Partnership Agreement (PPA) leaving Surf City as the sole sponsor of the federal project. Because of the funding constraints associated with DRA 2019 funding, specifically the requirement to construct the entire authorized project, a General Reevaluation Review (GRR) was determined necessary to use the funds to construct the Surf City portion as a standalone element. This resulted in the creation of the Surf City CSRM GRR which includes all the previously investigated borrow areas for the Surf City and North Topsail Beach CSRM project and the West Onslow Beach Coastal Storm Damage Reduction (CSDR) project.

During this time, Borrow Area A was reevaluated, and the Wilmington District developed High Confidence Volumes for those areas within and beyond 3 nautical miles (territorial sea limit). These volumes do not represent the total amount of available material, but instead represent the estimated volume of material that could be taken from the borrow area with a high degree of confidence in both the quality and quantity of material. These volumes were established by raising the original dredge cut depths to an elevation that avoids all instances of cemented sand, rock fragments, and cemented gravel found in the field descriptions of the boring logs. Note: dredge box delineations and/or volumes are subject to change and should only be regarded as drafts that are currently under development (Figure 36). The High Confidence Volumes for Borrow Area A (Figure 36) include a total of approximately 10.6 million cubic yards with approximately 9.5 million cubic yards within 3 nautical miles and approximately 1.1 million cubic yards beyond 3 nautical miles. The total estimated volume of material in Borrow Area A is approximately 13.5 million cubic yards. While this interpretation represents a reduction in overall borrow material, it is not expected to impact the life of the project. Additional geotechnical investigations are ongoing to further delineate beach quality material suitable for placement at Surf City.

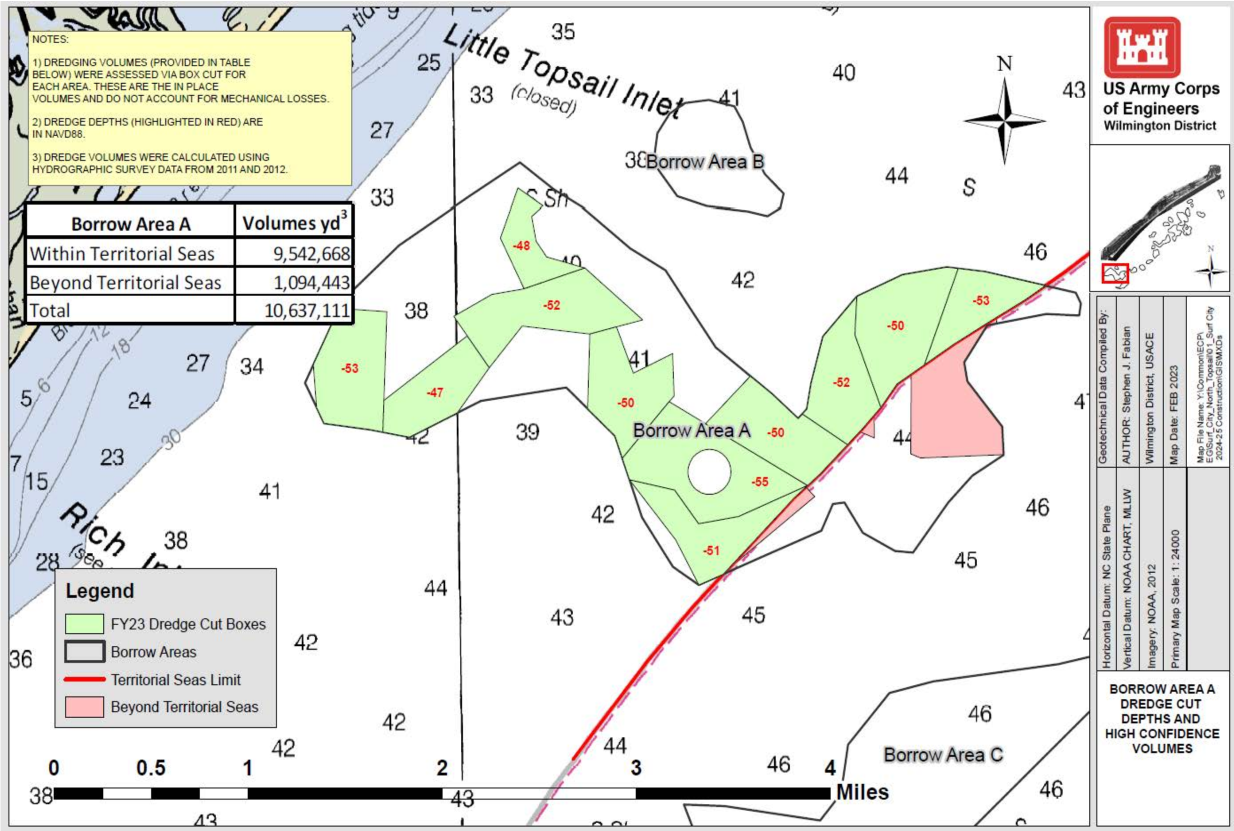


Figure 36. Borrow Area A dredge cut boxes and High Confidence Volumes within and beyond 3 nautical miles (territorial sea limit). (Dredge box delineations and/or volumes are subject to change and should only be regarded as drafts that are currently under development.)

Document 2:

Surf City and North Topsail Beach North Carolina
Coastal Storm Risk Management
Pre-Construction, Engineering, and Design Phase:
Geotechnical Appendix
28 May 2020

1 Introduction

Borrow areas for the Preconstruction Engineering and Design (PED) phase of the Surf City and North Topsail Beach, North Carolina Coastal Storm Damage Reduction (CSDR) Project were assessed in 2011 and 2013. Respective data were re-verified in April 2020 prior to initial beach nourishment construction scheduled for November 2020, as an authorized shore protection project for the towns of Surf City and North Topsail Beach, which are the two northern most towns on Topsail Island. The primary purpose of the PED phase for this project is to evaluate borrow areas identified for the project and to develop the design documentation for the most suitable plan of protection for the present and near future conditions at Surf City and North Topsail Beach. The products from the PED phase will be used to further this project toward construction of a berm and dune (with terminal transitions) along approximately 10 miles of the oceanfront. Project limits are the boundary between Topsail Beach and Surf City to the southwest, and to the northeast, the southern edge of the Coastal Barrier Resources System (Topsail Unit, L06) located within North Topsail Beach (Figure 1).

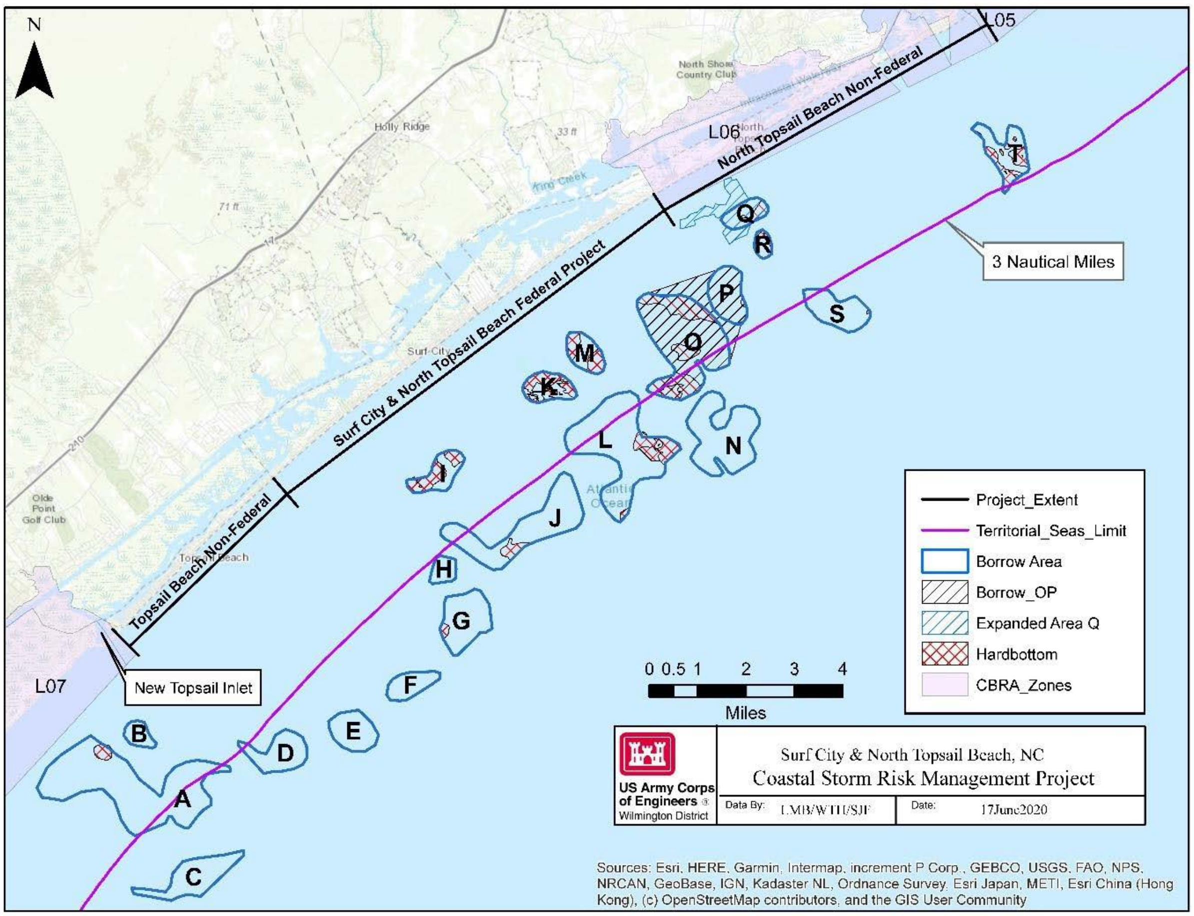


Figure 1. Location and vicinity map.

2 Previous Subsurface Investigation

An initial subsurface investigation was performed in 2003 from May to November for Topsail Beach, Surf City, and North Topsail Beach. A total of 369 borings were collected ranging from 1 to 6.5 miles offshore Topsail Island all water depths greater than 30 ft (MLLW). Borings were performed offshore of Topsail Island, in Banks Channel behind the town of Topsail Beach, and within the inlet and connecting channel between the Atlantic Intracoastal Waterway (AIWW) and New Topsail Inlet. Of the 369 collected borings, 167 were performed offshore of Topsail Island. The subsurface and geophysical data collected were used to identify and define borrow area locations and extents for both West Onslow Beach and New River Inlet (Topsail Beach), NC CSDR Project and the Surf City and North Topsail Beach, NC CSRM. The PED phase for the Surf City and North Topsail Beach project was executed in two phases, the first phase occurring in 2011 and the second phase in 2013. Phase I focused on Borrow Areas G, H, J, L, O, and P collecting 210 vibracores. Phase II focused on Borrow Areas E, F, N, R, and S collecting an additional 88 vibracores. Obtaining borings outside the boundaries were necessary in determining the continuity of sand resources between borrow areas. Borrow areas are further discussed in the Borrow Site Geology Section and are depicted in Figures 4 and 5.

3 Geologic Framework

Regional Geology

Physiography and Geomorphology

The project site encompasses Topsail Island and nearshore Onslow Bay. Topsail Island is a 26-mile-long modern, sediment starved, migrating, transgressive barrier island, which lies within the Atlantic Coastal Plain Physiographic Province. It is bounded by New River Inlet to the northeast, New Topsail Inlet to the southwest, Onslow Bay to the southeast, and the Atlantic Intracoastal Waterway (AIWW) to the northwest. Onslow Bay is a modern embayment of the Atlantic Ocean and is bounded by Cape Lookout to the north and Cape Fear to the south (Figure 2). New River Inlet and New Topsail Inlet are southwestwardly migrating inlets. Additionally, beaches, dunes, marshes, and landforms typical of barrier island complexes, are present on Topsail Island. Due to the frequency of storms, lack of fluvial sediment input, and interruption of longshore transport, erosion has occurred to nearly all dunes and grasslands on the island. Additionally, the nearshore floor of Onslow Bay mostly consists of submarine scarps, shoals, and bars.

Coastal Processes

Dynamic coastal processes continually shape the barrier islands of southeastern North Carolina. Rivers and streams entering Onslow Bay are volumetrically small with low gradients. Their continentally derived sediment loads are small when compared to large, fluvial geomorphic systems outside of NC. In addition, much of this fluvial sediment becomes trapped within the river estuaries and does not reach the ocean. This lack of significant sediment discharge into Onslow Bay limits the build-up of nearshore continental shelf sand deposits. As a result, naturally occurring sand recharge onto Topsail Island is limited, which makes the island vulnerable to seasonal storms and longshore currents which cause severe episodic shoreface erosion (Cleary, 1968; Sarle, 1977; Riggs *et al.*, 1996; Cleary, 2002). For a more in depth explanation of the coastal processes affecting the regional geology of Onslow Bay please see USACE document West Onslow Beach and New River Inlet (Topsail Beach), NC Coastal Storm Damage Reduction, Geotechnical Appendix, Section 3.5, Geomorphology Topsail Island and Onslow Bay.

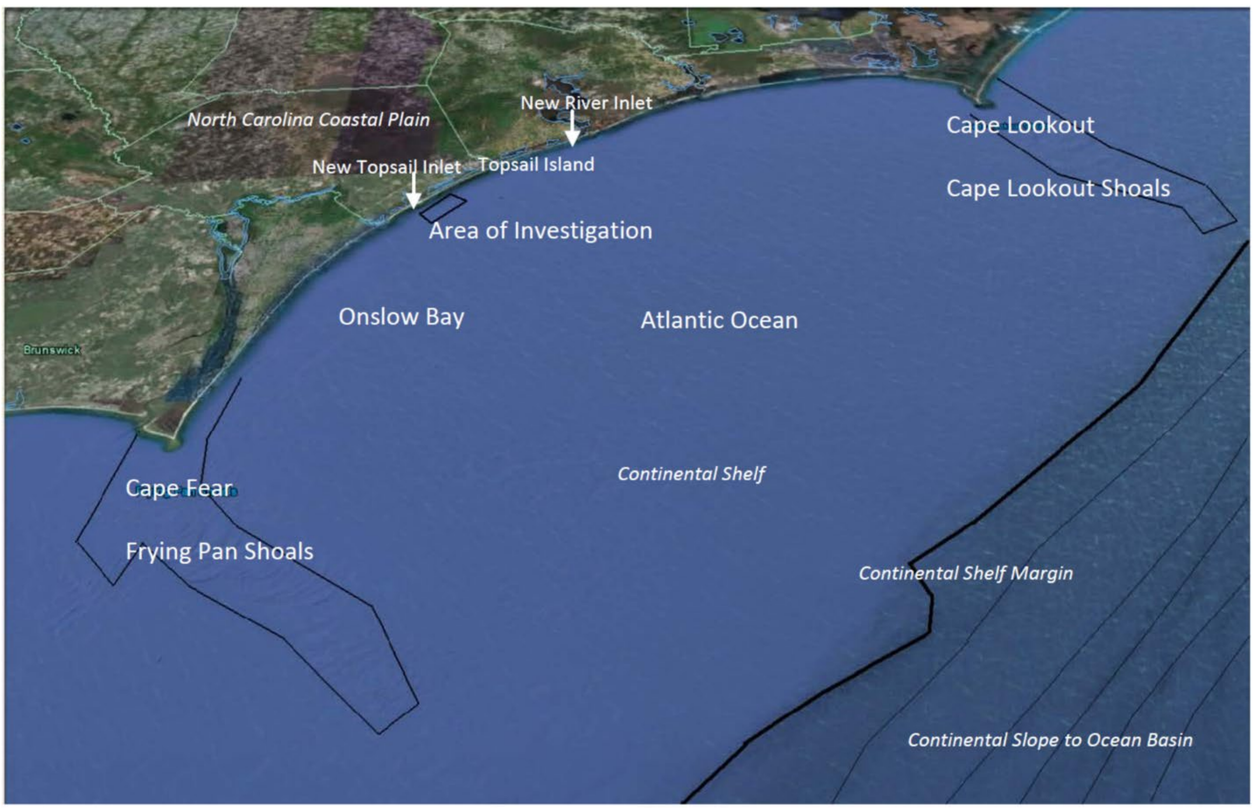


Figure 2. Major geographic features of investigation area (modified from Google Earth).

Stratigraphy

The Atlantic Coastal Plain and the inner continental shelf of Onslow Bay are underlain by nearly flat-lying sedimentary units which gently dip and thicken to the southeast.

This large sedimentary wedge includes unconsolidated sediment, slightly cemented sand units, and rock units. The oldest (lowest units) were deposited during the Cretaceous Period, 144 to 65 million years ago. The youngest part of the wedge dates to the Quaternary Period, 1.8 million to 10,000 years ago. This sedimentary wedge overlies pre-Mesozoic (older than 248 million years ago) crystalline basement rock (Harris and Zullo, 1991). A patchy veneer of Holocene (10,000 years ago to present) sand and gravel overlies the Quaternary strata in the project area.

The results from the geophysical and bathymetric surveys conducted in 2004 showed that shallow rock scarps and outcrops dominate and control the submarine topography offshore of Topsail Island. Although a surficial sand horizon was seismically resolved, it is discontinuous and separated by Oligocene rock outcrops. Erosion and reworking of this rock contribute coarse and fine-grained materials to the surficial sand, which decreases aesthetic value as beach fill. The thickest sequence of unconsolidated sediment occurs in or adjacent to the paleochannels. These sediments tend to be dominated by estuarine muds and fine sands and are unsuitable as beach fill. Borrow areas have been configured to avoid these channels.

Site Geology

Onslow Bay

The continental shelf in Onslow Bay is composed of a complex sequence of seaward dipping Tertiary age (65 million to 1.8 million years ago) strata, which were deposited during an age of periodic sea-level fluctuations (Hine and Riggs, 1986; Snyder *et al*., 1985; Snyder *et al*., 1986; Snyder *et al*., 1991).

The oldest rocks outcropping within the study area are Oligocene age (33.7 million to 23.8 million years ago) limestones submerged offshore of Topsail Island. Riggs *et al*. (1985) describe these limestones as the Belgrade and Trent formations, which consist of “moldic biomicrudite (Folk, 1974) limestones with interbedded calcarenite sands and grayish-green calcareous quartz sands.” A stratigraphically similar unit named the River Bend Formation, which consists of olive green quartz sand and silt, is reported to also underlie areas offshore of Topsail Island (Ocean Surveys, Inc., OSI, 2004). Northeast and east of the survey area lies a major unconformity separating the Oligocene rock and sediments from the younger Miocene (23.8 million to 5.3 million years ago) Pungo River Formation.

Quaternary paleofluvial channels, which generally trend normal to shore, crosscut the older strata offshore of Topsail Island. These channels were down cut during a period of lower sea level elevation. The paleofluvial channels are remnant streambeds, which were infilled with sediments during Pliocene to Pleistocene times (1.8 million years ago to 10,000 years ago; Snyder *et al*., 1994), and were drowned during the Holocene sea-level rise (Belknap, 1982; Hine and Snyder, 1985, Snyder and Snyder, 1992).

Surficial Holocene sedimentary deposits are scarce offshore of Topsail Island in Onslow Bay. Much of the native beach sand is derived from the physical and biological erosion of Oligocene rock and strata submerged in Onslow Bay (Figure 3). These sediments are then reworked, redistributed, and deposited within submarine valleys and ridges, or along the shoreface of Topsail Island (Cleary, 1968; HDR, 2002; HDR, 2003; Meisburger, 1979; McQuarrie, 1998; Riggs *et al*., 1996; Snyder and Snyder, 1992). A more thorough review and depiction of the structure and stratigraphy of Onslow Bay can be found in USACE document West Onslow Beach and New River Inlet (Topsail Beach), NC Coastal Storm Damage Reduction, Geotechnical Appendix, Sections 3.2 – 3.4.

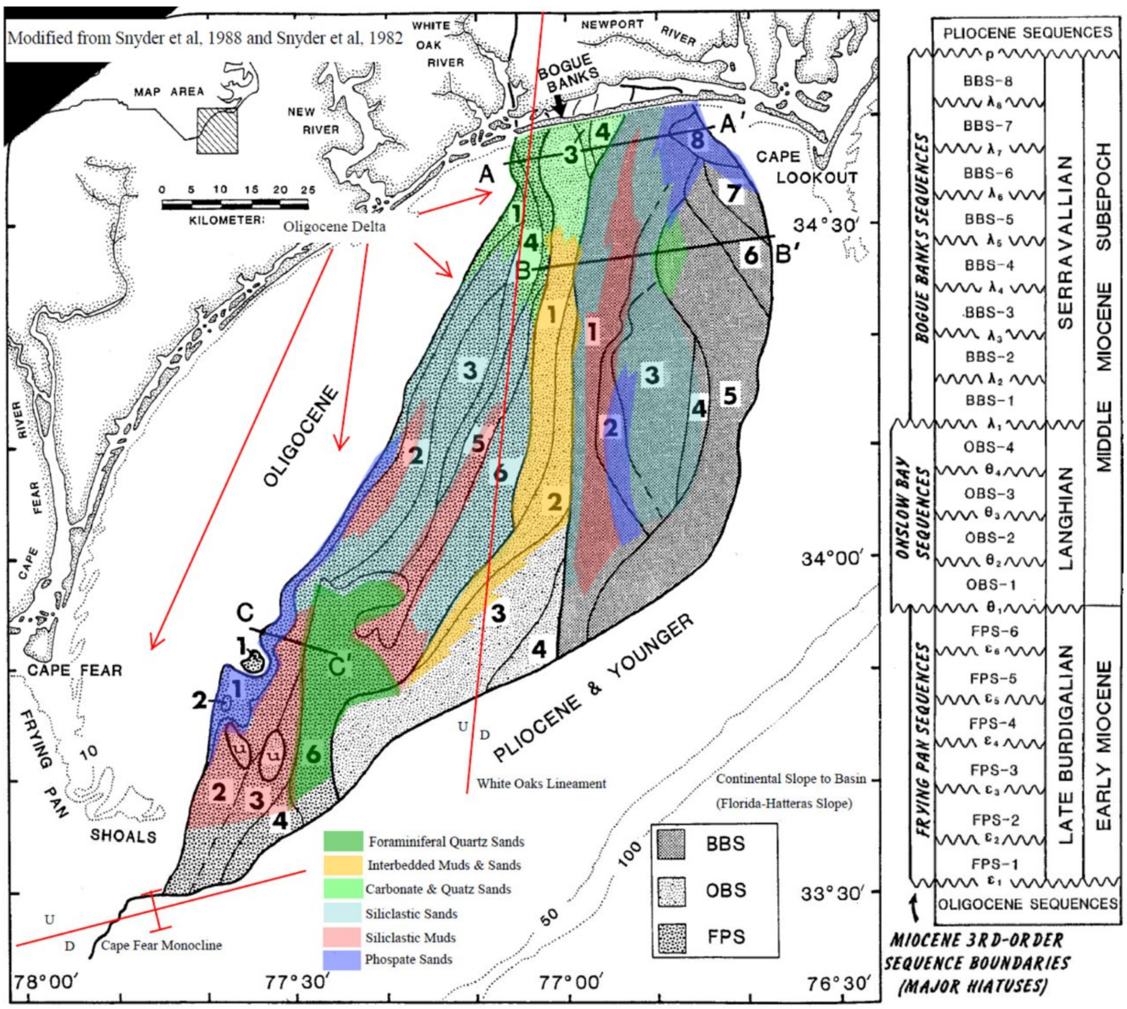


Figure 3. Seismic stratigraphy and lithology offshore Onslow Bay (modified from Snyder et al., 1988 and Snyder et al., 1982).

Topsail Island

Topsail Island overlies older Onslow Bay strata, with granular island beach material generally classified as fine- to medium-grained poorly graded sands according to the Unified Soil Classification System (USCS). These sands are the result of a complex combination of factors. Part of the sand is accumulated from storm overwash and longshore drift. Biological, chemical, and physical erosion of nearshore sedimentary rocks provides another source of sedimentation on the island. Winnowing by wind and wave action results in the predominantly fine- to medium-grained poorly graded sands on the beach today. Sediment accumulation is negligible (Riggs et al., 1996; Cleary, 2002) and natural sediment accumulation/recovery has not kept pace with erosion and/or sea level rise (Horton et al., 2007) exacerbating already high rates of shoreline recession (Thieler et al., 2000).

Borrow Site Geology

Background for Borrow Areas

Borrow Areas E, F, G, H, J, L, N, O, P, R, and S lie approximately 7 miles southwest of New River Inlet and approximately 7 miles northeast of New Topsail Inlet. The borrow areas extend offshore between a distance of 1.6 to 5.4 miles (Figures 4-5). The seafloor within the vicinity of the borrow areas is floored primarily by weathered Oligocene silty sandstone, outcroppings of Oligocene limestone hard bottoms (Cleary, 2002), and paleofluvial channels (Figures 3-5). With no significant sedimentation occurring from riverine discharge, Onslow Bay has scarce surficial Holocene sedimentary deposits (Ocean Surveys, 2004; Greenhorne & O'Mara, Inc., 2004). Instead, the embayment consists of mostly eroded and reworked sediments which often results in thin veneers of sediment overlying Oligocene outcrops and Quaternary channel fill sequences of variably sandy material (HDR, 2002; HDR, 2003; Meisburger, 1979; McQuarrie, 1998).

Confirming the potential presence of limestone and siltstone outcrops within the offshore Topsail Island study area was accomplished using high resolution geophysical and hydrographic surveys (i.e. side-scan sonar and multi-beam survey) performed by Mid-Atlantic Technology and Environmental Research, Inc. (M-AT/ER). Nearshore survey anomalies containing different backscatter returns or elevation changes were labeled as “potential hard bottom” warranting future ground truth efforts to assess the presence or absence of hard bottom (Hall, 2005). Hard bottom consisting of high, moderate, and low relief based on elevation changes were identified in several of the borrow areas. Anamar Environmental Consulting, Inc. conducted *in-situ* diver ground truthing of several borrow areas in the Spring of 2008. In August 2008, State and Federal resource agencies concurred with a USACE Wilmington District proposal to establish a hard bottom buffer consisting of 1,640 feet (500 meters) for moderate to high relief hard bottom and 400 feet (122 meters) for low relief hard bottom. These buffers were incorporated around respective hard bottoms present within each borrow area (Figures 4-5). The following sections discuss details associated with all work conducted offshore of Topsail Island using geophysical and hydrographic surveying and subsequent ground truth efforts to confirm the presence or absence of hard bottom features in both the nearshore environment and offshore borrow area.

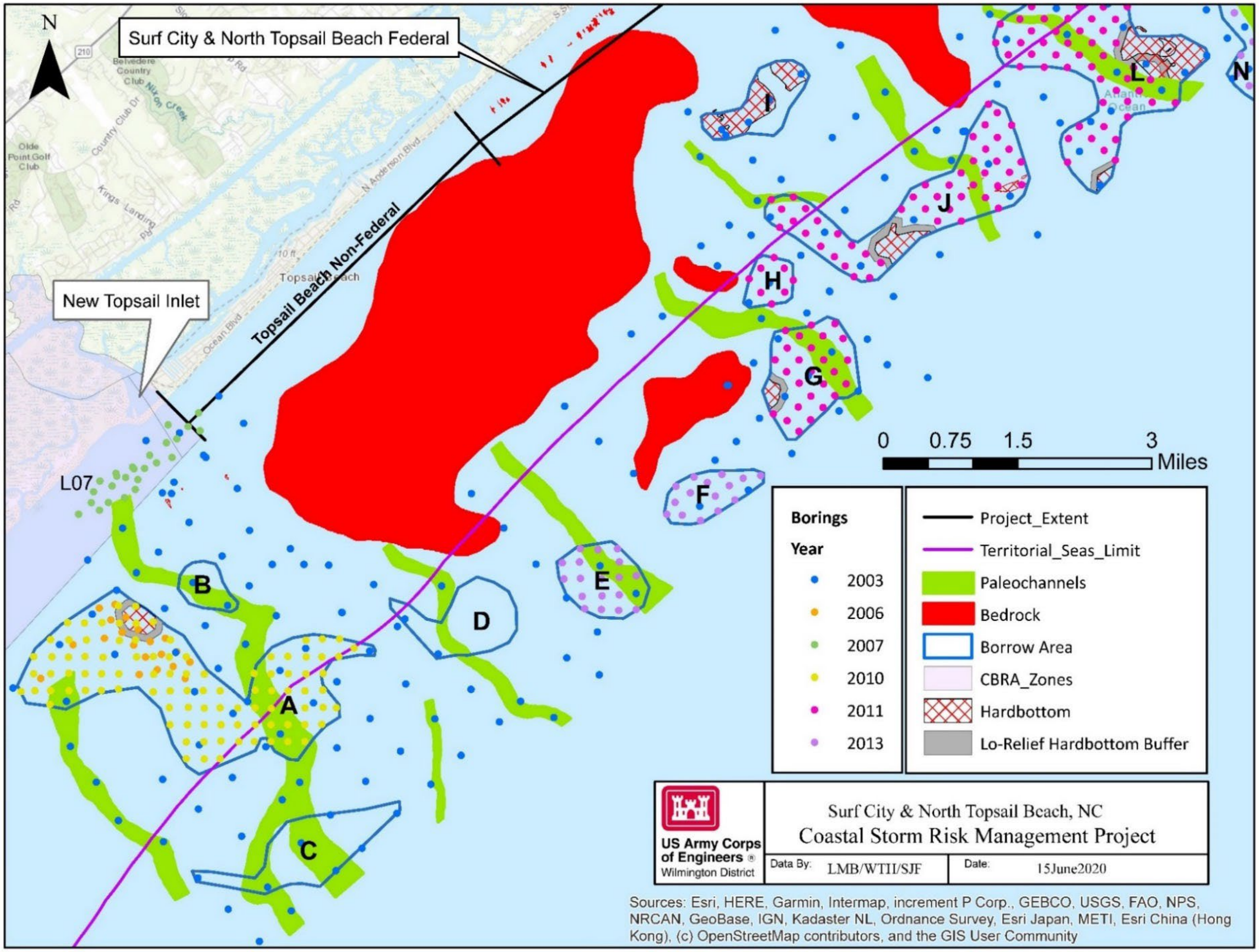


Figure 4. Southwest Map Section of USACE borrow areas and vibracore locations.

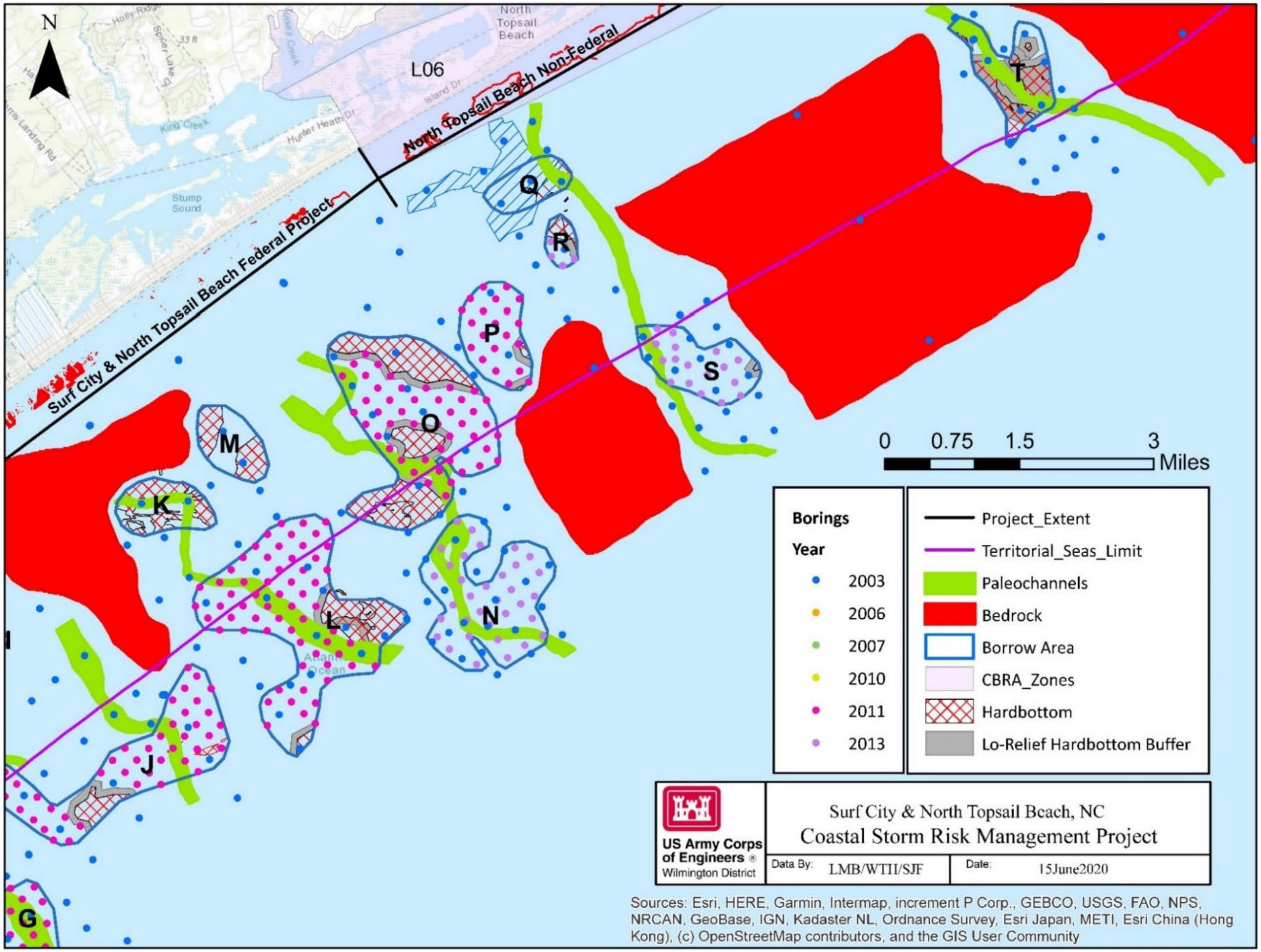


Figure 5. Northeast Map Section of USACE borrow areas and vibracore locations.

Nearshore Surveys

From October 2004 to May 2005, M-AT/ER performed nearshore side-scan sonar surveys offshore Topsail Island from the shoreface to the -30 feet MLLW contour. The nearshore side-scan data provided a visual representation of the change in density of the surface material on the ocean bottom. Interpretation of side-scan sonar data identified several areas which had higher density material than the adjacent area. These high backscatter “finger-like” projections were located cross-shore throughout the survey area. Based on these density differences, the areas of high backscatter were considered “potential hard bottom” targets and were delineated for future ground truth investigation. Generally, these targets started approximately 800 feet offshore and extended to the end of the survey, located approximately 1,800 feet offshore. Additional multi-beam surveys were conducted on these isolated targets and data interpretation of seafloor bathymetry indicated that areas of high backscatter with cross-shore orientation identified in the side-scan sonar survey were gradual seafloor depressions with approximately 1.5 feet vertical relief per 330 feet horizontal distance. In order to further characterize the substrate of these depressional features, USACE coordinated with National Oceanic and Atmospheric Administration (NOAA) Fisheries to dive on representative sites and gather surface sediment grab samples. Anamar Environmental Consulting, Inc. conducted the *in-situ* diver ground truthing and concluded that there were small areas of hard bottom resources within Borrow Areas G, J, L, O, and P. In addition, samples were retrieved from both within and outside of the identified depressions. Most of the sediment samples retrieved outside of the depressions (areas of low backscatter) were characterized as fine-grained sand. Samples retrieved from within the depressions (areas of high backscatter) were generally a coarser sandy shell hash and, in two samples, contained small (3.0 inches x 2.0 inches) limestone cobbles.

The features identified in Surf City and North Topsail Beach, and West Onslow Beach and New River Inlet via geophysical and hydrographic surveys, and ground truth efforts are consistent with previously identified “rippled scour depressions (RSD)” (Cacchione *et. al*., 1984; Thieler *et. al*., 1999; Thieler *et. al*., 2001), “ripple channel depressions (RCD)” (McQuarrie, 1998), or “sorted bedform” (Murray and Thieler, 2004) features. Though termed differently throughout the literature, RSD, RCD, and sorted bedforms are considered interchangeable terms to identify the same geologic feature. According to McQuarrie (1998), an approximately 39 square mile area was surveyed using side-scan sonar, high resolution seismic, and vibracores on the shoreface and inner shelf of Onslow Bay. This study characterized the inner shelf off Topsail Island as Tertiary and Pleistocene outcrops with a thin, discontinuous, loose surficial sheet of sediment. In addition to shore-perpendicular quaternary fluvial channels, wave and current action on the shoreface generates “ripple channel depressions.” A significant amount of historic side-scan data has been collected offshore of Topsail Island (1992, 1994, and 1996)

(Rob Thieler, Personal Communication, March 2007; McQuarrie, 1998) which match well with the nearshore side-scan survey conducted by Greenhorn and O'Mara (2006 and 2007). Evaluating these two data sets provided additional insight into the offshore extent and stability of these features. Considering that the data are spread over a 15-year timeframe and imagery from the surveys still match well, it appears that these features are fairly stable, at least over a decadal time frame (Rob Thieler; Personal Communication, March 2007). This stability suggests that these features are maintained by the localized interaction of oceanographic processes and poorly sorted bed material. Specifically, these features represent a recurring, preferential morphologic state to which the seafloor returns after storm induced perturbations. This apparent stability is interpreted to be the result of interactions at several scales that contribute to a repeating, self-reinforcing pattern of forcing and sedimentary response which ultimately causes the RSD's to be maintained as bedforms responding to both along-and across-shore flows. According to Dr. William Cleary (Personal communication, March 2007), the presence of RSD's/sorted bedforms as identified through side-scan imagery off Topsail Island are ubiquitous from North Topsail Beach through Wrightsville Beach.

Based on the comprehensive evaluation of the nearshore data collected through side-scan and multi-beam survey techniques, diver ground truth surveys, and additional historic offshore side-scan data, it was concluded that previously documented "potential hard bottom" targets are consistent with descriptions RSD, RCD, and sorted bedform features (Figures 4-5).

PED Survey Data

In 2011 and 2013, USACE contracted Geodynamics to perform a high-resolution survey of the seafloor surface for evaluating underlying geology, sediment quantity, and potential hard bottom. The 2011 investigation focused on Borrow Areas G, H, J, L, O and P, while the 2013 investigation focused on Borrow Areas E, F, N, R, and S. Figures 7 and 8 show interpreted areas of "potential hard bottom" based on bathymetry, amplitude, and backscatter acoustic intensity. Areas with high acoustic backscatter signatures (lighter colors) suggest "harder" or coarser ocean floor material. Both reports (2011 and 2013) noted that ground truth information was necessary to confirm the composition and structure of these features. As previously noted in this report some of the borrow areas (G, H, J, L, O, and P) were ground truthed by Anamar Environmental Consulting, Inc. and several small areas were determined to contain hard bottom. In general, results from this report were very similar to previously documented "sorted bedform" features and are believed to be extensions of those documented in the nearshore environment.

In the 2011 PED Phase I investigation, an additional 210 vibracores were completed by the USACE Vessel SNELL in order to further refine sediment quantity and quality within Borrow Areas G, H, J, L, O, and P. Several of the vibracores overlapped the areas documented by Geodynamics as “potential hard bottom” targets and serve as an additional means of ground truth for subsurface sediment. The sediment samples from the vibracores within these targets confirmed that the area was unconsolidated sediment generally consisting of coarse- to fine-grained sand. Considering the results of the ground-truthing vibracores and the previously documented “sorted bedform” features just inshore of the borrow site, it is assumed that the regions identified by Geodynamics as “potential hard bottom” are actually extensions of the sorted bedform features extending offshore and perpendicular to the shoreface. In the 2013 PED Phase II investigation, an additional 88 vibracores were completed by Athena Technologies within Borrow Areas E, F, N, R, and S. While the 2013 vibracore investigation identified significant quantities of cemented sands and gravels, no hard bottom was identified.

In addition to the hydrographic survey, Geodynamics completed geophysical surveys of the borrow areas investigated for Phase I and Phase II of PED. The geophysical data were collected at 1,000 foot intervals using an EdgeTech sb512i compressed high intensity radar pulse (CHIRP) sub-bottom reflection sonar with EdgeTech Discover acquisition software. The CHIRP sub-bottom tracks lines are shown in Figure 9. The black circles indicate the start and end of each line. An example CHIRP image is provided in Figure 6.

The CHIRP images were used to identify sub-bottom material changes and to assist in identifying suitable sedimentary material. For Phase I of PED, several of the vibracore borings had already been completed and analyzed prior to the completion of the geophysical survey. Nevertheless, survey images were used to validate the compatibility analysis, which is discussed later in this report. For Phase II of PED, the vibracore borings had been completed prior to any of the CHIRP images having been processed. For the Phase II investigation, however, significant layers of cemented sands and gravels were found in the vibracores, with varying degrees of cementation, which was not the case in the Phase I investigation. The CHIRP images were more representative of actual in-situ material at depth for the Phase I vibracores. The CHIRP images for Phase II were not representative at depth, due to the varying degrees of cementation, but do generally mimic the thin surface layers and isolated pockets of beach-fill quality material with the borrow areas.

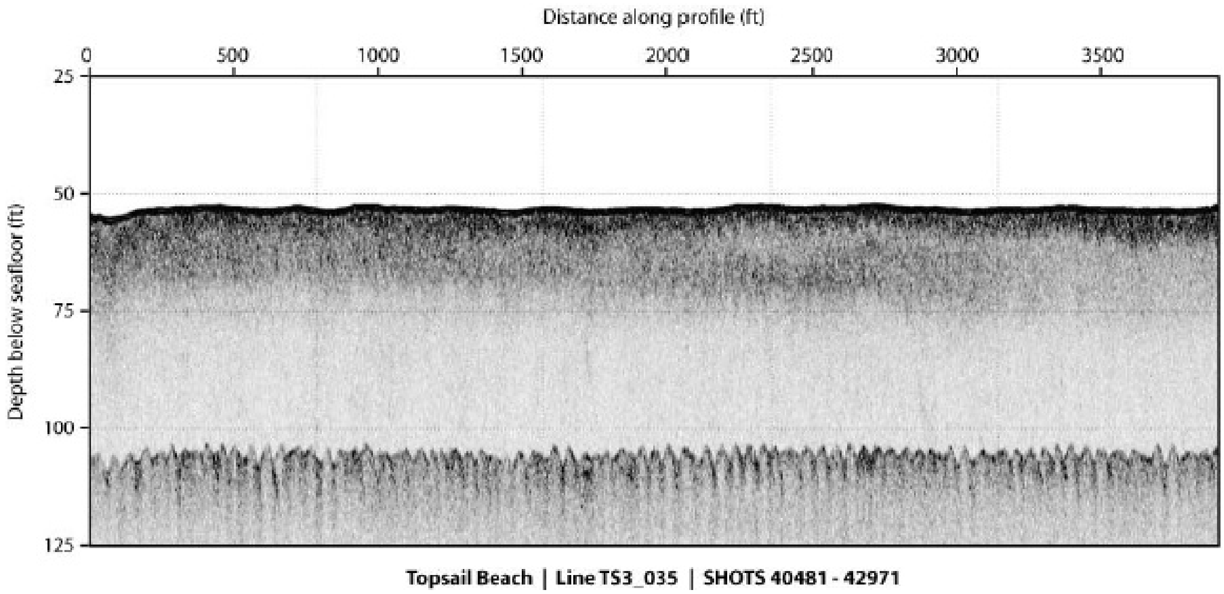


Figure 6. Sample CHIRP image.

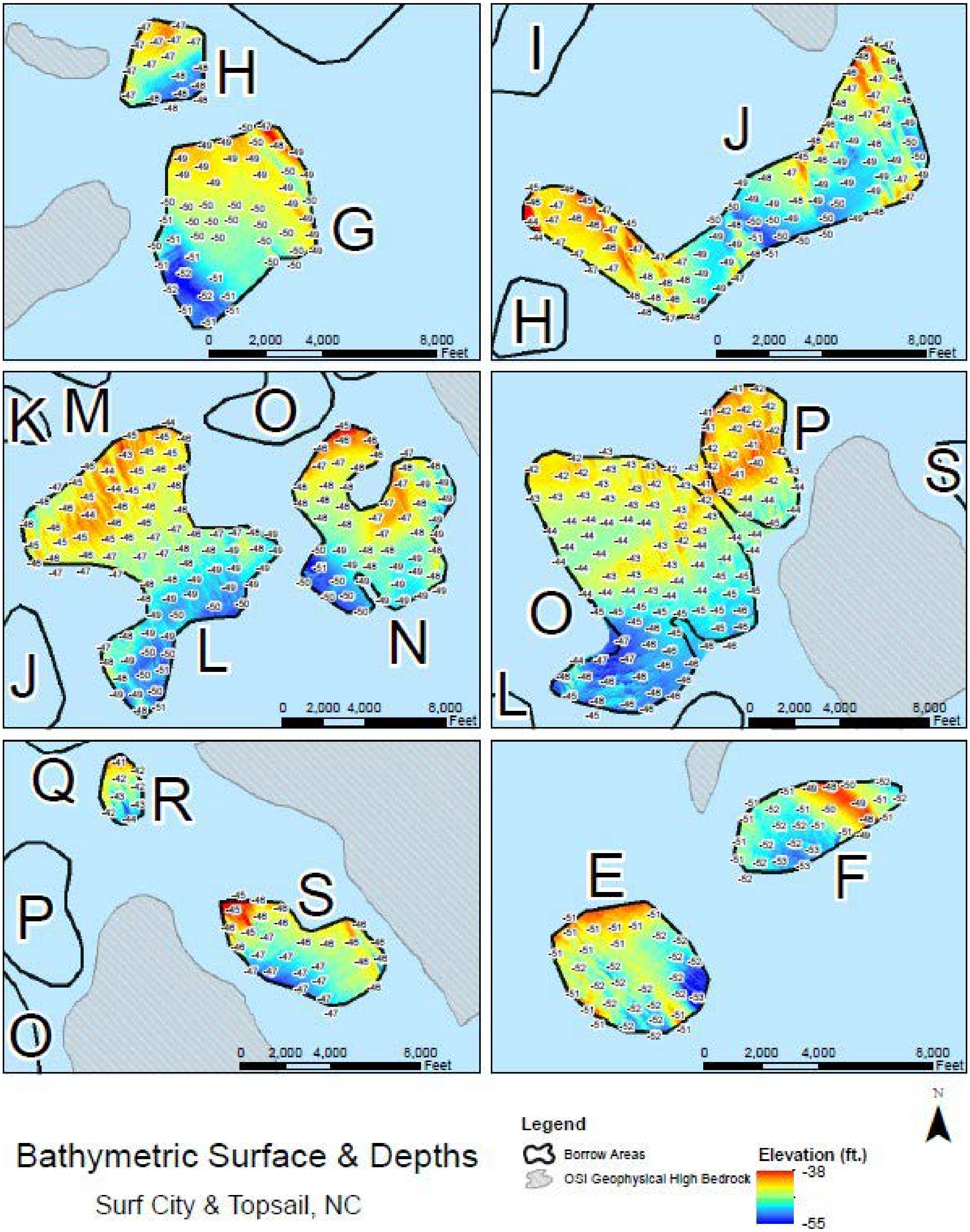


Figure 7. Bathymetric surfaces and depths for investigated borrow areas (NAVD88).

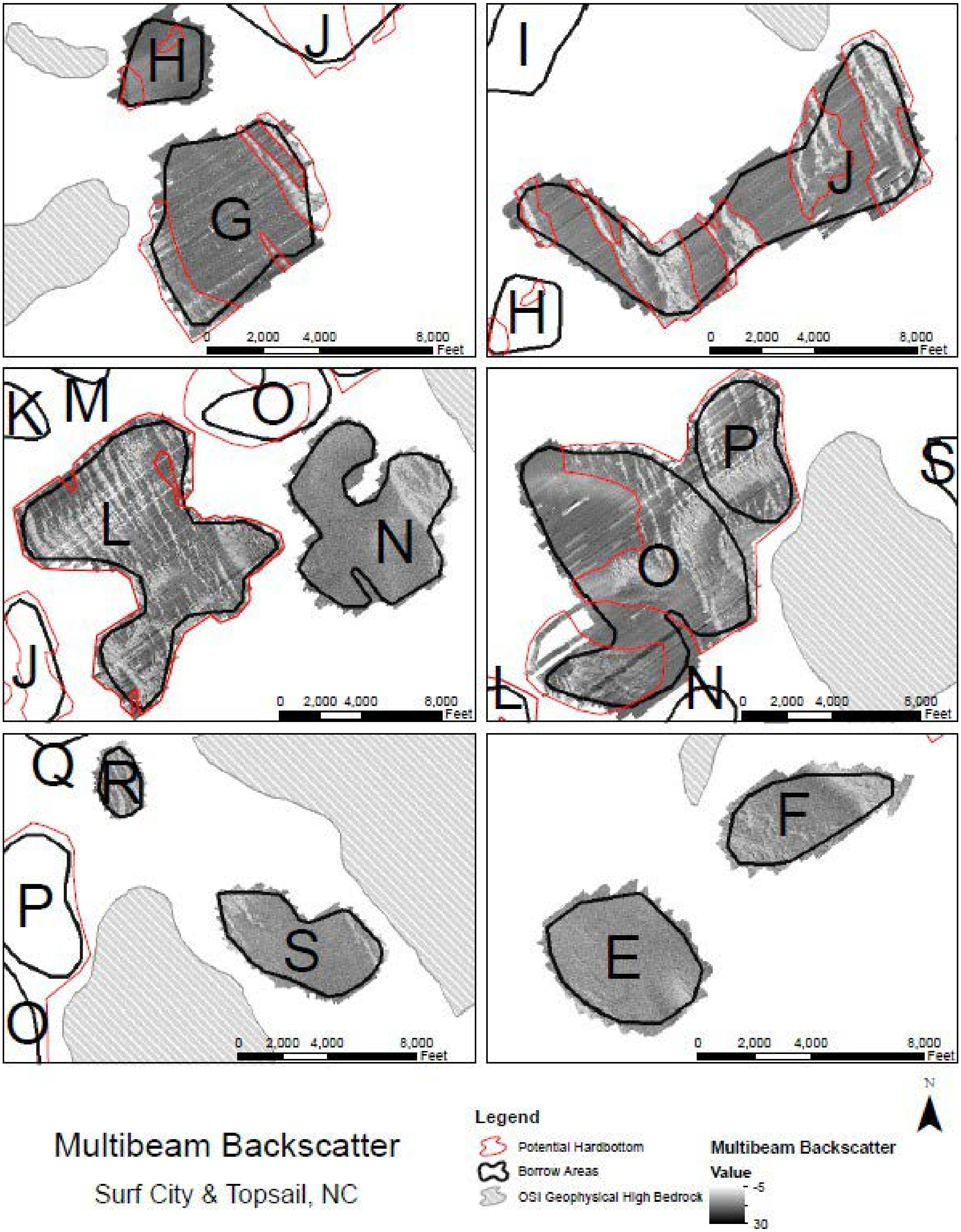


Figure 8. Multibeam backscatter for investigated borrow areas (NAVD88).

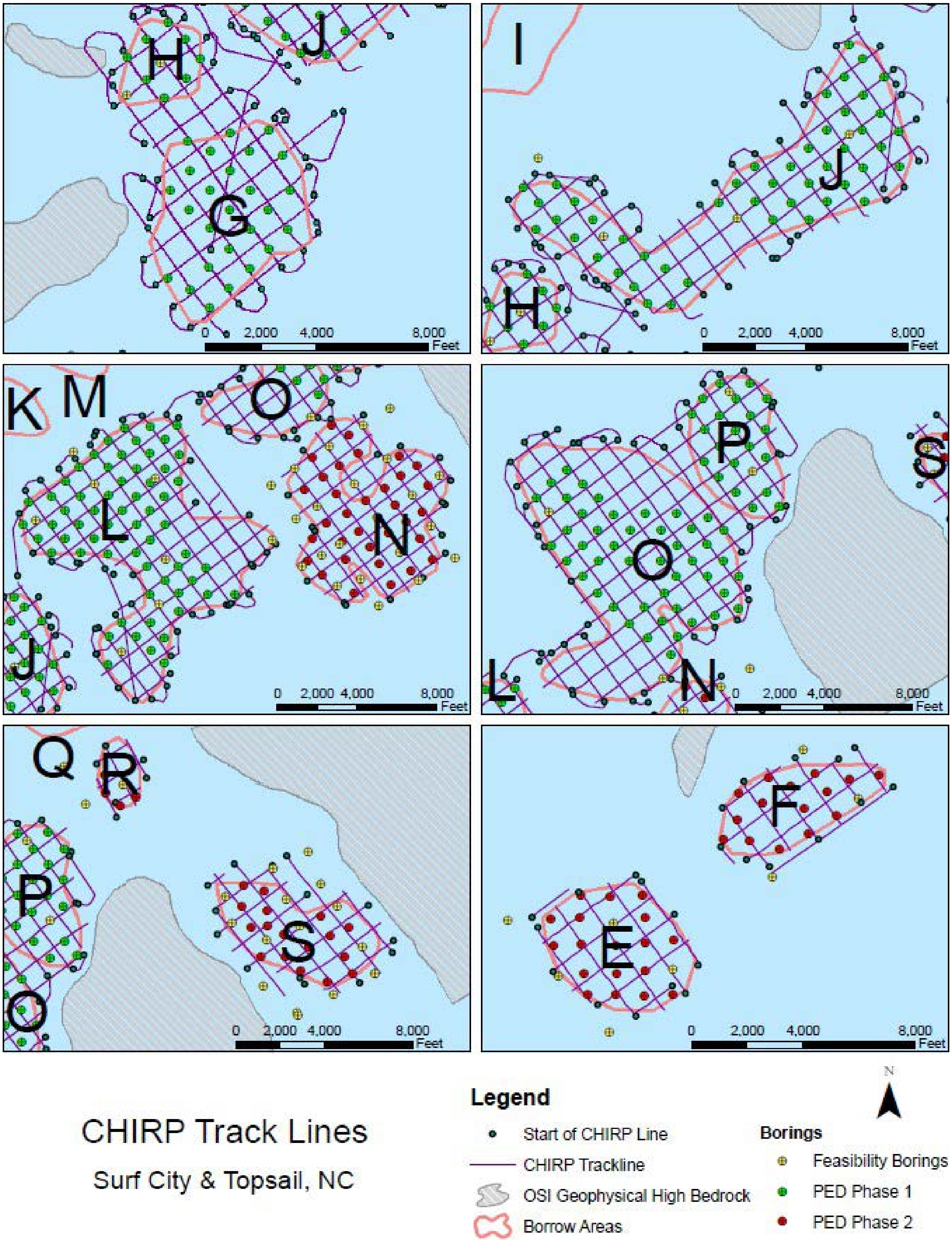


Figure 9. CHIRP track lines for investigated borrow areas.

4 Methodology

Native Beach Sampling

Native beach sampling was performed in 2003 under the guidance of 15A NCAC 07H.0312 Technical Standards for Beach Fill Projects. The native beach sampling encompasses all of Surf City from the south end of the project boundary to the far north end of North Topsail Beach at New River Inlet. However, the native beach grain size includes only those samples within the project limits of Surf City and North Topsail Beach CSDR Project. The sampling of the native beach material was conducted using 5,000 ft intervals and was concentrated in two areas, the foreshore which extends from mean low water (approximately 1.9 feet below National Geodetic Vertical Datum, NGVD29) landward to the seaward toe of the dune, and the offshore which extends seaward from mean low water to a depth of 23 feet below NGVD29. Grab samples were collected by USACE along ten transects (TB-7 to TB-16) for the Surf City and North Topsail Beach CSDR project (Figure 10) at the surface at the following elevations: Toe of the Dune, Crest of the Berm, Mean High Water (MHW), Mean Sea Level (MSL), Mean Low Water (MLW), and 12 samples collected seaward of MLW starting at elevation -3 feet MLW and continuing at 2 foot increments from -4 to -24 feet MLW (see Figure 10 for a definition sketch of terminology). CPE provided two additional grab samples for transects TB-13 to TB-16 one at the toe of the dune and one sample landward of the MLW. The composite characteristics for transects TB-7 to TB-12 were determined by using all 17 of the USACE grab samples, while the composite characteristics for transects TB-13 to TB-16 used 11 of the USACE grab samples and the two grab samples provided by CPE. The 13 samples from transects TB-13 to TB-16 were from the Dune, Toe of the Dune, Crest of the Berm, Mean High Water (MHW), Mean Sea Level (MSL), Mean Low Water (MLW), one sample landward of the MLW, and six samples seaward of the MLW line (-6.0, -8.0, -12.0, -14.0, -18.0, -20.0 feet MLW). The results from the composite characteristics were used to evaluate compatibility of borrow area material.

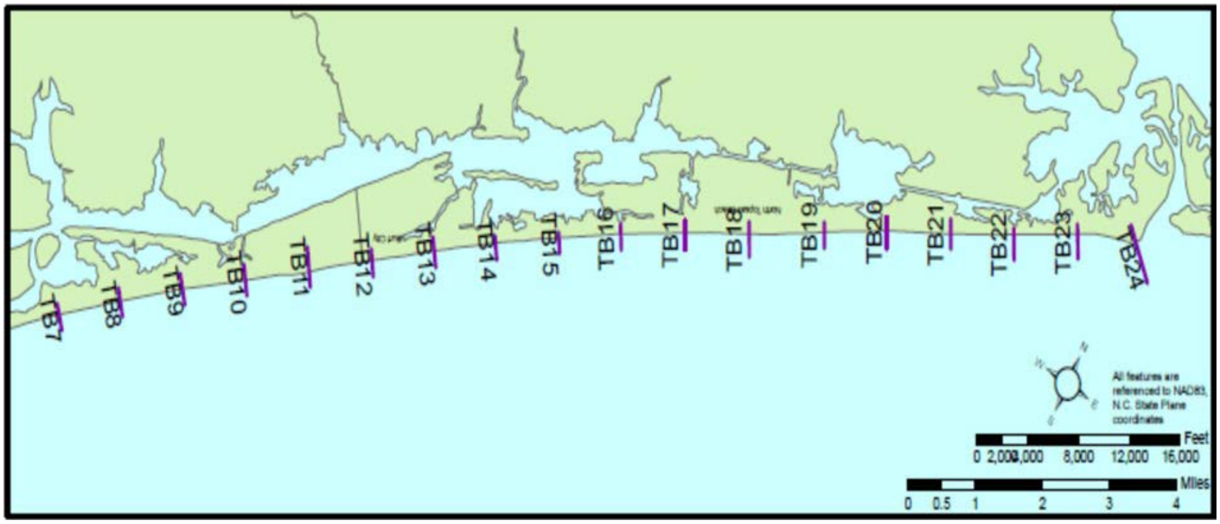


Figure 10. Topsail Beach native beach transects at 5,000 foot intervals.

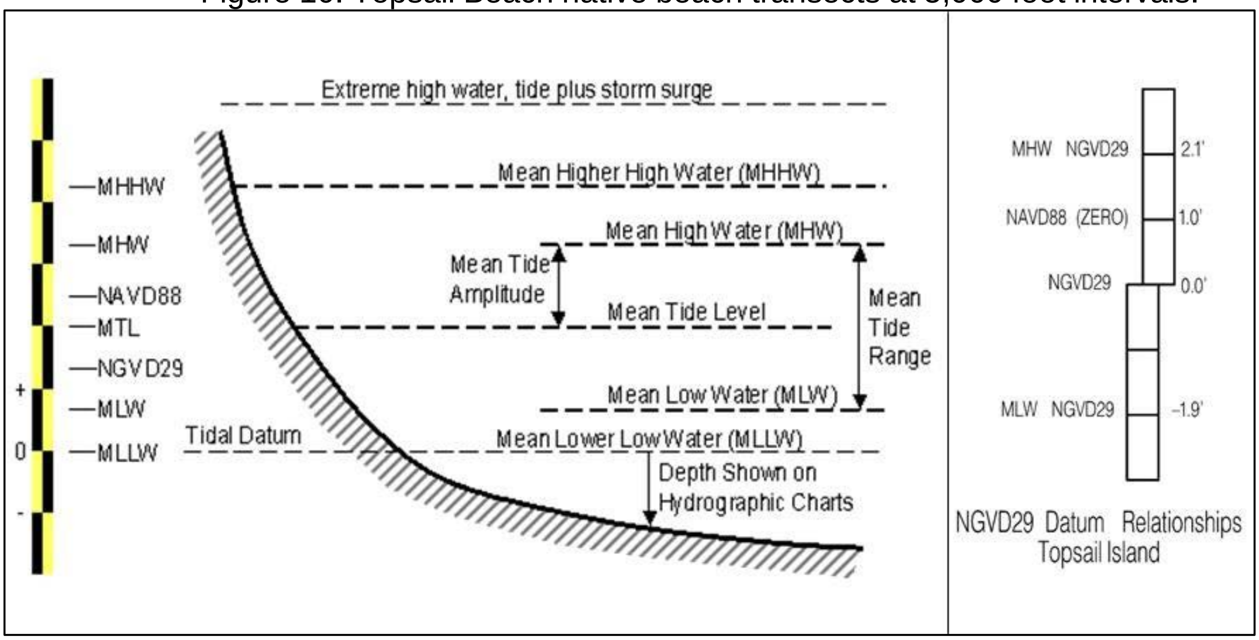


Figure 11. Sketch of NOAA tide level terminology (US DOT, 2012).

Note: The mean grain sizes of the native and borrow area materials are reported in phi (ϕ) units in this report, where phi is related to the grain size as follows:

$$\phi = -\log_2(d)$$

where:

d = grain size in millimeters (mm)

$\log_2$ = logarithm to the base 2

Since the distribution of the sand samples can generally be represented as log-normal distributions, the standard deviations and variances of the particle size distributions are reported in phi units. The Surf City and North Topsail Beach native beach mean phi value was determined to be 2.15 ± 0.73 and the composite data from the samples had a mean of 1.3 percent fines and 9.4 percent shell. The composite results from each of the sampling intervals are listed in Table 1 along with the overall composite result for the native beach.

Table 1. Native beach sampling results for Surf City and North Topsail Beach.

Sampling Transect	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	% Shell	Weight % Passing #10
TB-7	2.23	0.73	1.84	11.76	98.82
TB-8	2.07	0.9	1.35	13.00	96.86
TB-9	2.26	0.69	1.49	9.88	96.04
TB-10	2.22	0.67	1.81	10.41	98.49
TB-11	1.95	0.94	1.11	13.88	96.80
TB-12	2.21	0.67	1.32	10.94	97.46
TB-13*	2.09	0.76	1.24	7.31	99.63
TB-14*	2.22	0.56	0.88	4.92	99.81
TB-15*	2.09	0.78	1.10	5.31	98.87
TB-16*	2.20	0.64	0.81	6.54	98.47

Native Beach Composite	
Mean (phi)	**2.15**
Std Dev (phi)	**0.73**
Weight % Fines (passing #230)	**1.3**
Visual % Shell	**9.4**
Weight % Pass #10	**98.1**

*For transects TB-13 to TB-16 only 13 samples were used to determine the composite data, while transects TB-7 to TB-12 used 17 samples.

Subsurface Sampling

The 2003 and 2011 subsurface investigations were performed using the USACE Vessel SNELL and an Alpine Model #270 vibracore drill. The vibracore is a self-contained pneumatic powered vibratory corer that has a 20-ft metal barrel into which a clear Lexan 3 7/8-in. diameter liner (vibracore tube) is inserted for collecting sediment. The liner is held in place by a metal shoe that is screwed onto both the liner and metal barrel. A cutting edge is included in the metal shoe. The vibracore machine uses a pneumatic powered vibrator mounted at the uppermost end of the vibracore barrel. The machine is mounted in a stand that can be lowered to the seafloor by a crane. When the vibracore is activated the vibracore barrel vibrates into the unconsolidated sediment and a disturbed sediment sample is retained inside the liner. In general, vibratory drilling collects 10 to 20 ft of sediment unless refusal is encountered. Refusal can occur when the penetration rate of the vibracore is less than 0.01 feet/second. The survey-grade HYPACK navigation system on the USACE Vessel SNELL was used to determine the boring locations. The seafloor bottom elevation was determined by measuring water depth from the water line to the subsurface, with water line datum as 0.0 feet. The recorded water depth was then corrected to MLLW using NOAA-verified tidal data for the date and time for which the vibracore were drilled. Once tide-corrected, the recovered vibracore tubes are ready for field classification and sample processing. After processing was complete, vertical datums were converted to NAVD 88 based on the survey data provided by Geodynamics (2012). The 2003 sampling effort collected 369 vibracores of which 167 were offshore of Topsail Island. The 2011 sampling effort collected 210 vibracores offshore of Surf City and North Topsail Beach.

The 2013 subsurface collection of 88 vibracores was performed by Athena Technologies using the 35 foot research vessel Artemis and Athena's custom designed vibracore system. The custom vibracore machine "consists of a generator with a mechanical vibrator attached via a cable. The vibrator is attached directly to a three-inch diameter galvanized sample barrel. The sample barrel is then lowered to the sea floor through a moonpool in the deck of the sampling platform by attaching lengths of drill stem. The vibracore machine is then turned on and the sample barrel is allowed to penetrate until it reached twenty feet or refusal. The sample barrel is then retrieved using an electric winch. Once the sample is on deck, the core is measured, cut, capped, and labeled" (Athena Technologies, 2013). The recovered vibracore tubes were then delivered to USACE for field classification and sample processing. Boring locations were determined by means of survey-grade HYPACK and a Furuno fathometer (accurate to 0.1-feet). Final horizontal and vertical positioning was established using a Trimble R8 Global Navigation Satellite System (GNSS) interfaced with the North Carolina RTK network (Athena Technologies, 2013; NAVD88).

Laboratory Testing

The vibracore tubes from the 2003, 2011, and 2013 subsurface investigations were taken to the Wilmington District, Snow's Cut field facility, where they were cut open, logged, and field classified in accordance with the Unified Soil Classification System (USCS). Samples were collected from each tube at approximately 2 ft intervals or at each visible change of material. The retained samples were stored in jars and sent to a USACE certified soils laboratory for particle-size analysis. A particle-size analysis was conducted on each sample in accordance with ASTM Standard D 422, "Standard Test Method for Particle-Size Analysis of Soils" using the following 16 U.S. Standard sieve sizes: 3/4", 3/8", No. 4, No. 7, No. 10, No. 14, No. 18, No. 25, No. 35, No. 45, No. 60, No. 80, No. 120, No. 170, No. 200, and No. 230 sieve. For the 2013 subsurface investigation vibracores U.S. Standard sieve sizes No. 5 and No. 40 were used in addition to the previously stated set. In addition to the particle-size analysis, all the samples were classified using visual engineering soil classification in accordance with ASTM Standard D 2487, “Classification of Soils for Engineering Purposes (Unified Soil Classification System)” as required in Engineering Manual 1110-1-1804 and a visual estimation of the percent shell content was performed. Table 2 contains some of the USCS definitions pertaining to the materials documented within the borrow areas.

Table 2. USCS definitions (based on ASTM-2487).

Major Division		**Group Symbol**	**Group Name**	**Criteria**
F_{200}<50	Gravel R_4/R_{200}>0.5	GP	Poorly graded gravel	F_{200}<5; C_u≥4, 1≤C_z≤3
	Sands R_4/R_{200}≤0.5	SW	Well-graded sand	F_{200}<5; C_u≥6, 1≤C_z≤3
		SP	Poorly graded sand	F_{200}<5, Does not meet the SW criteria of C_u and C_z
		SM	Silty Sand	F_{200}>12, PI<4
		SC	Clayey sand	F_{200}>12, PI>7
		SW-SM	Well-graded sand with silt	5≤F_{200}≤12, satisfies C_u and C_z criteria of SW and PI>7
		SP-SM	Poorly graded sand with silt	5≤F_{200}≤12, does not satisfy C_u and C_z criteria of SW and PI<4
		SP-SC	Poorly graded sand with clay	5≤F_{200}≤12, does not satisfy C_u and C_z criteria of SW and PI>7
F_{200}>50	Silts and Clays LL≥50	MH	Sandy silt	≥30% plus No. 200, % sand ≥ % gravel
		CH	Fat clay	<30% plus No. 200, <15% plus No. 200
			Fat clay with sand	<30% plus No. 200, 15-29% plus No. 200, % sand ≥ % gravel

Note: C_u = uniformity coefficient
C_z = coefficient of gradation
LL = liquid limit
PI = plasticity index

R_4 = percentage retained on the No.4 sieve
R_{200} = percentage retained on the No.200 sieve
F_{200} = percentage finer than the No.200 sieve

5 Subsurface Investigation Results

Spatial Analysis

Spatial analysis was conducted using ArcMap and gINT software to delineate potential resource subsections within the borrow areas, as well as identify problematic zones containing undesirable material. The 2011 and 2013 field and lab data and select 2003 USACE boring logs were input into the gINT geotechnical database program, which facilitated drafting of boring logs and 2-D geologic fence diagrams. Forty-three 2-D geologic fence diagrams were generated in gINT and their orientations were drawn in ArcMap (Figures 12-57). The intent of each diagram is to verify the thickness of potentially useful strata utilizing the soils data. Each profile conveys the following information: ocean bottom, bottom of boring, graphical representation of the visually classified soils, laboratory soil classification in parenthesis, and proposed dredge cut areas.

Before looking at the individual borrow areas, it is important to understand the differences between field classification and laboratory classification. Field classification of a sample consists of estimating grain sizes in hand, in addition to qualitatively recording sample moisture, plasticity, and other physical attributes such as cementation or the presence of shells. Laboratory classification is performed according to ASTM (American Society for Testing and Materials) Standards, D421 and D422, to identify the range of grain sizes and weight percentage of each grain size relative to the entire sample. In this process, the sample is physically broken up twice in a mortar using a rubber-covered pestle, after which the sample is placed in a stack of sieves which are used to separate the different grain sizes. The stack of sieves is shaken vertically and horizontally for several minutes.

While the laboratory data are used for performing compatibility analysis it would be irresponsible to presumptively value these data over that which is gathered with field classifications. The field classifications most closely represent the condition of the material in-situ, the same condition in which the material will ultimately be dredged. While the dredging process disturbs in-situ material, there is no evidence to suggest that dredging would physically alter it as much as laboratory preparation. Additionally, field classifications allow for the identification of friable limestone or other indurated or partially indurated grains, which laboratory analysis might classify as being SW or SP. Therefore, for the purpose of beach renourishment, materials field classified as cemented or as gravels are not being considered.

It is apparent in several of the following 2D fence diagrams that significant discrepancies exist between field classifications and laboratory classification, specifically in Borrow Areas F, N and S. As explained in the previous paragraphs these discrepancies result from the different techniques utilized by each method of classification. Additionally, the horizontal spacing of the vibracores within each borrow area should be considered. Generally, the PED level investigation of the borrow areas for the Surf City & North Topsail project were done at 1,000 foot grid spacing. It is important to note; however, in a coastal depositional environment the subsurface can change significantly over 1,000 feet. While some may argue that a smaller interval should be required, the 1,000 foot grid spacing has historically worked well. Therefore, these diagrams are approximations of the *in-situ* sediment conditions based on field classifications, lab classifications, and geotechnical interpretation.

Consideration of minimum sand thickness for constructability and economic viability is also important. In terms of constructability, the minimum thickness required is a function of the type of dredge being utilized. Typically, a hopper-style dredge is the most capable when dredging thin veneers of material (less than 2.0 feet). However, it is uncommon to dredge material less than 2.0 feet in thickness simply because it isn't economically viable in most cases.

Also of importance is the need to maintain a vertical buffer between suitable beach fill material and unsuitable beach fill material. In most of the 2-D fence diagrams, which include proposed dredge cuts, it is apparent that the maximum dredge depths are shallower than the depth of suitable beach fill material. This is the result of suitable beach fill material being underlain by material that is unsuitable. The vertical buffer is required to help prevent the dredging of unsuitable material, which may occur from errors of vertical placement of dredging equipment. The thickness of the vertical buffer depends on a combination of engineering judgment and how unsuitable the underlying material is. For example, a clean sand (SP) with 4 percent fines (passing the #200 sieve) underlain by a silty sand (SM) with 13 percent fines (passing the #200 sieve) would warrant a vertical buffer of 0.5-feet, due to the fact that if some of the silty sand ended up on the beach it would likely not be a significant problem. Conversely, if the same clean sand were underlain by poorly graded gravel (GP) a much larger vertical buffer would be warranted, such as 2.0-feet. Generally, for this project, vertical buffers range from 1.0 to 2.0 feet.

Figures 12-57, located on pages 30-75, directly following these summaries, contain the fence diagram locations and subsurface profiles[1]. Portions of borrow areas marked with a crosshatch pattern are areas of unsuitable material or suitable material that is not of sufficient thickness to dredge. Areas without a crosshatch pattern and no dredge depth are hardbottom and hardbottom buffer zones. Please note when viewing the maps that

[1] Fence diagrams depict subsurface sampling and sediment type. Those areas displaying a white background and a black X, denote the final drill depth of the vibracore but with zero sample recovery preventing further classification.

Borrow Areas E, F, R, and S are no longer being utilized for construction or renourishment of the project, and consequently contain little signage or symbology other than the vibracores completed within in each area and the locations of the fence diagrams.

Borrow Area E (Figures 4 and 12)

Figures 13, 14, 15, and 16 contain geologic cross sections E1, E2, E3, and E4, respectively, from within Borrow Area E. Map orientations for each fence diagram are found in Figure 12. Material characteristics consist of a thin veneer of sand (less than 2.0 ft thick) at the surface underlain by SM containing fines of 13 to 28 percent passing the #200 sieve. This thin veneer is best observed in cross section E3. Due to the high silt content beneath the sand and risk of entraining underlying, unsuitable material during the dredging process, no compatibility analysis was done on this borrow area. Consequently, this borrow area is being eliminated as it contains no dredgable beach-fill.

Borrow Area F (Figures 4 and 12)

Figures 17, 18, and 19 contain geologic cross sections F1, F2, and F3, respectively, from within Borrow Area F. Map orientations for each fence diagram are found in Figure 12. This borrow area contains no hardbottom or hardbottom buffer area and is relatively small in comparison to the other borrow areas. This borrow area has only a few isolated and thin pockets of sand at the surface. As seen in the cross sections, the majority of the material has been field classified as gravel. Additional notes on the individual vibracore logs state that in many cases the gravel was cemented. Most of the gravel was laboratory classified as SP-SM and SM. It is likely that the field classified gravels were in fact cemented sands that met the grain size distribution requirement for beach-fill. However, regardless of the fines in the SP-SM, dredging cemented materials often results in the deposition of lithoclasts onto the beach. Consequently, this borrow area is being eliminated as it contains no dredgable beach-fill.

Borrow Area G (Figures 4, 12, and 58)

Figures 20, 21, and 22 contain geologic cross sections G1, G2, and G3, respectively, from within Borrow Area G. Map orientations for each fence diagram are found in Figure 12. Borrow Area G has a 3.5 to 7.0 foot thick deposit of sand across the central area. The northeastern and southernmost portion of the borrow area generally contains a thin layer of sand (less than 1.0 foot) that is underlain by silt with 17 to 20 percent fines (passing #200 sieve). These thin veneers are being avoided as dredging these areas is not viable. The 3.5 to 7.0 foot thick sand deposit across the central area of the borrow area contains SP and SP-SM, with the SP-SM having 8 to 11 percent fines. Composited, there are 5 percent fines in the proposed dredge cuts. Most of the proposed dredge cuts are limited by the depth of the vibracores, rather than unsuitable material. Depths for vibracores SC-11-V-194 and -197 are limited by SM material, having 12 to 16 percent fines. The material quality within the proposed dredge cuts for Borrow Area G is acceptable for beach-fill placement.

Borrow Area H (Figures 4, 12, and 58)

Figures 23 and 24 contain geologic cross sections H1 and H2, respectively, from within Borrow Area H. Map orientations for each fence diagram are found in Figure 12. Borrow Area H has a 9.0 to 18.0 foot thick deposit of sand across much of its midsection. In the southwestern and southeastern corners of the borrow area is a thin layer of sand underlain by MH to the southwest (with 58 percent fines passing #200 sieve, vibracore SC-11-V-181) and SM to the southeast (with 21 percent fines, vibracore SC-11-V-184). To the north is a thin layer of sand where the underlying material is unknown due to low recovery in vibracore TI03-V-260. Proposed dredge cut depths in the remainder of the borrow area are limited by the depth of each vibracore. Composited fines for the proposed dredge cut depths are 3.4 percent. The material quality within the proposed dredge cut depths for Borrow Area H is acceptable for beach-fill placement.

Borrow Area J (Figures 4, 25, and 58)

Figures 26, 27, 28, and 29 contain geologic cross sections J1, J2, J3, and J4, respectively, from within Borrow Area J. Map orientations for each fence diagram are found in Figure 25. Cross sections J1, J2, and J3 are in the southern half of the borrow area, separated from the northern section by a hardbottom and hardbottom buffer zone. Cross section J4 is in the northern portion. The availability of beach-fill material is patchy throughout the borrow area, due to a combination of thin layers of sand at the surface underlain by unsuitable material and the presence of unsuitable material within the entire column of several vibracores. In the southern portion of the borrow area, sand in vibracores SC-11-V-139 and 140 is too thin to dredge (cross section J2), while sand in 141 (cross section J2) is partially cemented according to the field classification. Vibracores SC-11-V-176 and 138 (cross section J3) each contain several feet of SM right at the surface with 17 to 19 percent fines passing the #200 sieve. The remaining areas consist of thin layers of sand (generally 2.0 ft) underlain by SM and SP-SM material, with fines ranging from 12 to 20 percent. In the northern portion, much of the area contains too thin a layer of sand to dredge. A narrow but shallow corridor is identified in cross section J4 and on the corresponding plan sheet, largely consisting of a 2.0 to 3.0 ft thick layer of SP underlain by SM with fines ranging from 13 to 14 percent. Not much of a buffer is utilized here due to the fines in the underlying material being relatively low and to allow dredging of the overlying beach-fill quality sand. Composited fines for the proposed dredge cut depths are 4.0 percent. The material quality within the proposed dredge cut depths for Borrow Area J is acceptable for beach-fill placement.

Borrow Area L (Figures 5, 12, and 59)

Figures 30, 31, 32, 33, and 34 contain geologic cross sections L1, L2, L3, L4, and L5, respectively, from within Borrow Area L. Map orientations for each fence diagram are found in Figure 25. Roughly 20 percent of the borrow area is eliminated due to existing hardbottom and the required hardbottom buffer, most notably in the southwest corner of the borrow area and in two smaller pockets in the northwest corner. There is a small pocket of sand in the northeast portion of the borrow area just east of a hardbottom buffer area, seen in cross section L5. The small pocket ranges in depth from 2.0 ft at the north end to 11.0 ft at the south end. Materials consist of SP and SP-SM with the SP-SM materials having 8 to 10 percent fines passing the #200 sieve. This pocket is underlain by SM material with 20 to 23 percent fines. There is a narrow corridor of suitable material through the center of the borrow area and more widespread areas of suitable material in the northeast portion. The narrow corridor is seen best in cross section L2 with depths ranging from 2.0 to 5.0 feet SP and SP-SM materials with the SP- SM having fine ranging from 9 to 11 percent. Cross section L3 intersects a thin veneer (about 2.0 feet) of suitable material in the northeast portion of the borrow area. Materials are mostly SP, generally underlain by SP-SM materials with fines in the 14 to 50 percent range. Cross sections L1 and L3 both intersect the southeastern corner of the borrow area and show there to be a thin layer of sand with up to 2.5 inch diameter rocks, underlain by SM material with fines in the 17 to 20 percent range. This area does not contain suitable material. Cross section L1 also intersects a few small but deep pockets of sand in the south-southwest portion of the borrow area with thicknesses of 3.0 to 8.0 feet. These pockets contain mostly SP-SM materials with fines in the 6 to 12 percent range underlain by SM materials with 14 to 17 percent fines. Composited fines for the proposed dredge cut depths are 5.0 percent. The material quality within the proposed dredge cut depths for Borrow Area L is acceptable for beach-fill placement.

Borrow Area N (Figures 5, 35, and 59)

Figures 36, 37, 38, 39, 40, 41, 42, 43, and 44 contain geologic cross sections N1, N2, N3, N4, N5, N6, N7, N8, and N9, respectively, from within Borrow Area N. Map orientations for each fence diagram are found in Figure 35. This borrow area is one of the larger sites and the largest investigated as part of PED Phase II. This borrow area contains no hardbottom or hardbottom buffer area but does have material variability and discontinuity in sediments. The best locations for beach-fill are noted in cross sections N4 (a small narrow pocket at the southeast corner), N6, N7, and N8, which transect a larger pocket of sand on the northwestern quadrant. The sand pocket identified in cross section N4 ranges in thickness from 4.0 to 6.0 feet, as seen in vibracores SC-13-V-01 and -03. This proposed dredge cut contains mostly SP but is limited by the field classified gravels identified below the sand layer in vibracore SC-13-V-03 and the high percentage of fines in other vibracores surrounding this narrow pocket. Cross section N3 is adjacent to N4 and contains field classified gravel in SC-13-V-04 as well as 15 to 18 percent fines passing the #200 sieve just inches below the surface in vibracores SC-13-V-05 and -06.

The larger sand pocket as identified in cross sections N6, N7, and N8 consists almost entirely of SP underlain in most vibracores by field classified gravels and by SM with 16 percent fines in vibracore SC-13-V-22. The persistence of the gravel below the sand layer is pronounced in cross sections N7 and N8. The only vibracore not limited in depth by gravel or fines content is SC-13-V-28 in cross section N6, which indicates that material below the proposed dredge depth is SP-SM with 8 percent fines. However, the lateral extent of the proposed dredge cut is limited by a thick gravel layer denoted in vibracore SC-13-V-27 (seen in cross sections N5 and N6) less than 1,000 feet away.

Throughout the rest of the borrow area, discontinuous pockets of sand and scattered thin sandy veneers exist. Given the level of discontinuity, and the risk associated with placing unacceptable material on the beach, the remainder of this borrow area is not being considered. Composited fines for the proposed dredge cut depths are 2.52 percent. The material quality within the proposed dredge cut depths for Borrow Area N is acceptable for beach fill placement.

Borrow Area O (Figures 5, 35, and 60)

Figures 45, 46, 47, 48, and 49 contain geologic cross sections O1, O2, O3, O4, and O5, respectively, from within Borrow Area O. Map orientations for each fence diagram are found in Figure 35. At least 50 percent of the borrow area is eliminated due to existing hardbottom and the required hardbottom buffer zones. A large pocket of suitable material in the south-southwest portion of the borrow area ranges in the thickness from 2.0 to 5.5 feet and consists of SP-SM material with 7 to 8 percent fines passing the #200 sieve (see cross sections O2 and O5). A large hardbottom buffer area exists in the center of the borrow area, around most of which are large sand deposits. Smaller areas of sand that were characterized as having in-situ cemented rock fragments (cross section O2, vibracore SC-11-V-57) or thin layers of suitable material overlying unsuitable material (cross section O5, vibracore SC-11-V-51) were not considered viable. For example, cross section O5, or vibracore SC-11-V-51 has 92 percent fines 1.5 feet below the surface and cross section O4, vibracore SC-11-V-27 has 17 percent fines less than 2.0 feet below the surface. Otherwise, suitable material, particularly that in cross sections O1, O4, and O5, ranges in thickness from 2.5 to 12 feet with the exception of the easternmost portion of cross section O4 which has a thickness of 18 feet. Suitable materials include SP and SP-SM with the SP-SM fines ranging from 6 to

10 percent. The suitable materials are generally underlain by SP-SM and SM with fines ranging from 11 to 18 percent. Composited fines for the proposed dredge cut depths are 6.7 percent. The material quality within the proposed dredge cut depths for Borrow Area O is acceptable for beach-fill placement.

Borrow Area P (Figures 5, 35, and 60)

Figures 50, 51, and 52 contain geologic cross sections P1, P2, and P3, respectively, from within Borrow Area P. Map orientations of each fence diagram are in found in Figure 35. A small pocket at the far north end of the borrow area has been eliminated due to the high silt content in vibracore SC-11-V-18 (cross section P3). Material within the top 2.0 ft at this location is classified as SM with 12 percent fines passing the #200 sieve. Much of the northeastern and eastern border of this borrow area have also been eliminated (see cross section P2), as vibracores SC-11-V-12 and -7 both contain over 2.0 feet of gravel at the surface. The rest of the borrow area contains suitable beach fill of 3.0 to 10.0 feet thick and is composed of some SP but mostly SP-SM material with fines ranging from 8 to 11 percent. The suitable material is generally underlain by SM with fines in the 12 to 20 percent range. Composited fines for the proposed dredge cut depths are 8.6 percent. The material quality within the proposed dredge cut depths for Borrow Area P is acceptable for beach fill placement.

Borrow Area R (Figures 5 and 35)

Figures 53 and 54 contain geologic cross sections R1 and R2, respectively, from within Borrow Area R. Map orientations of each fence diagram are found in Figure 35. This borrow area contains no hardbottom or hardbottom buffer and is relatively small in comparison to the other borrow areas. The site has a thin veneer of sand at the surface ranging in thickness from less than 1 to 1.5 feet. Below the sand layer, fines content ranges from 11 to 12 percent passing the #200 sieve. Thus, the surface sand layer is so thin that attempts to recover it via dredging would result in mixing with underlying unsuitable sediments, resulting in an unsuitable conglomeratic slurry which would be incompatible with the native beach. Consequently, this borrow area is being eliminated as it contains no dredgable beach-fill.

Borrow Area S (Figures 5 and 35)

Figures 55, 56, and 57 contain the geologic cross sections S1, S2, and S3, respectively, from within Borrow Area S. Map orientations of each fence diagram are found in Figure 35. This borrow area contains no hardbottom or hardbottom buffers and is relatively small in comparison to the other borrow areas. This borrow area has a thin veneer of sand at the surface ranging in thickness from 0.5 to 1.0 feet. Underlying the sand is generally either SM or gravel. The SM materials have fines in the range of 11 to 50 percent passing the #200 sieve. The field classified gravels in many cases were laboratory classified as SP-SM or SM. However, this in-situ material likely represents indurated or partially indurated sediments. As a result, dredging will likely result in the deposition of lithoclasts onto the beach. Consequently, this borrow area is being eliminated as it contains no dredgable beach-fill.

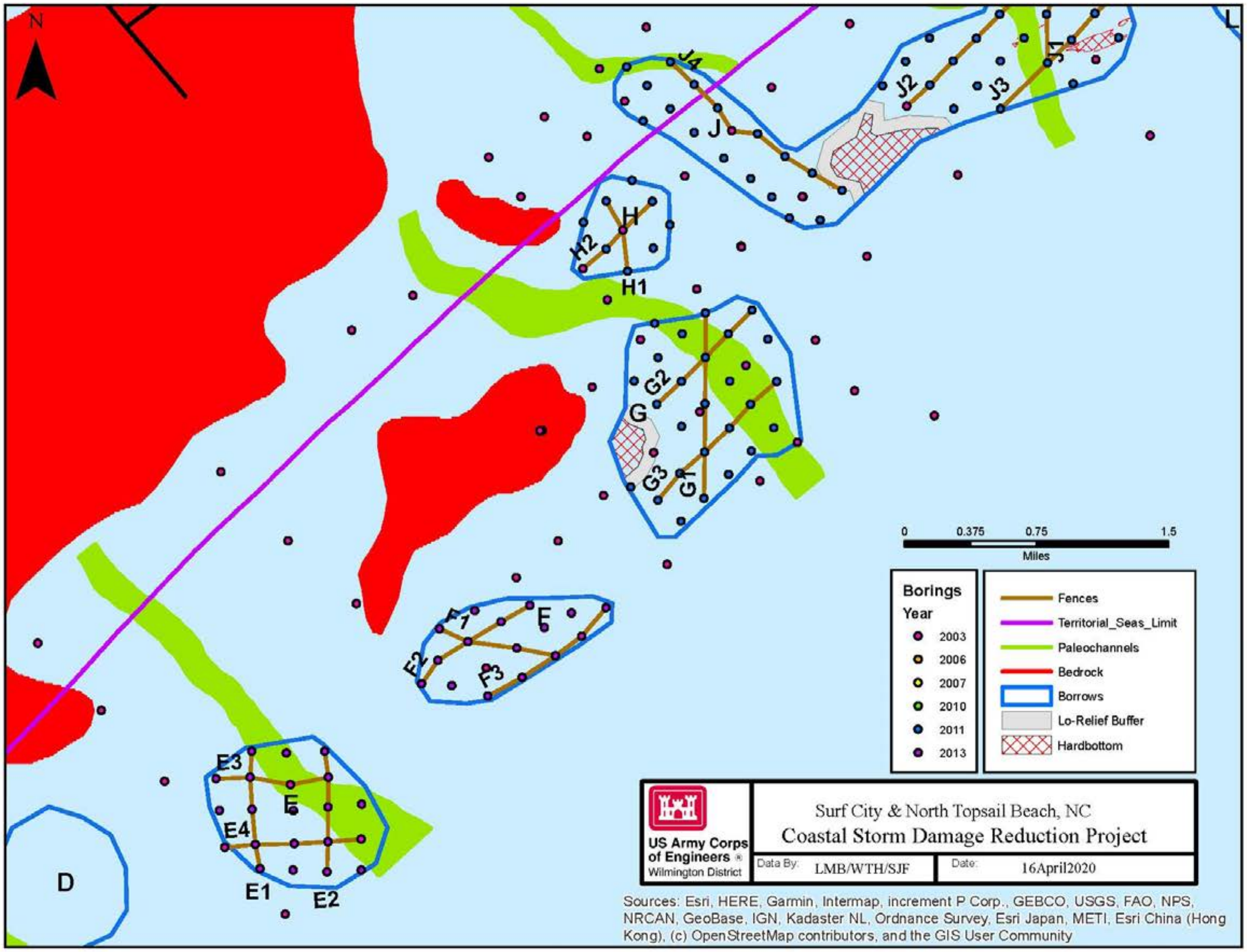


Figure 12. Geographic location of Fence Diagrams for Borrow Areas E-H.

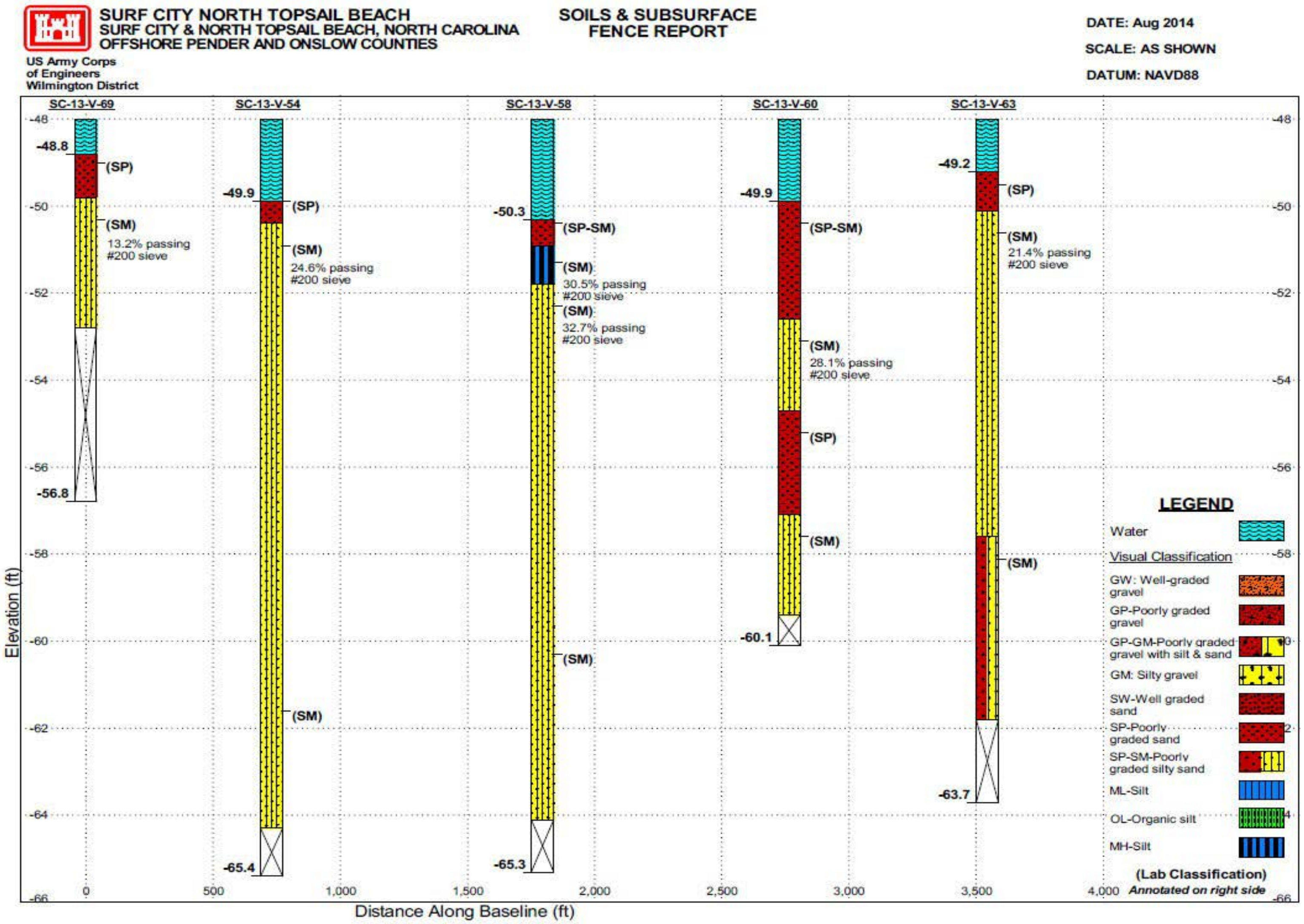


Figure 13. 2-D geologic cross section in Borrow Area E, profile E1. Bearing S to N.

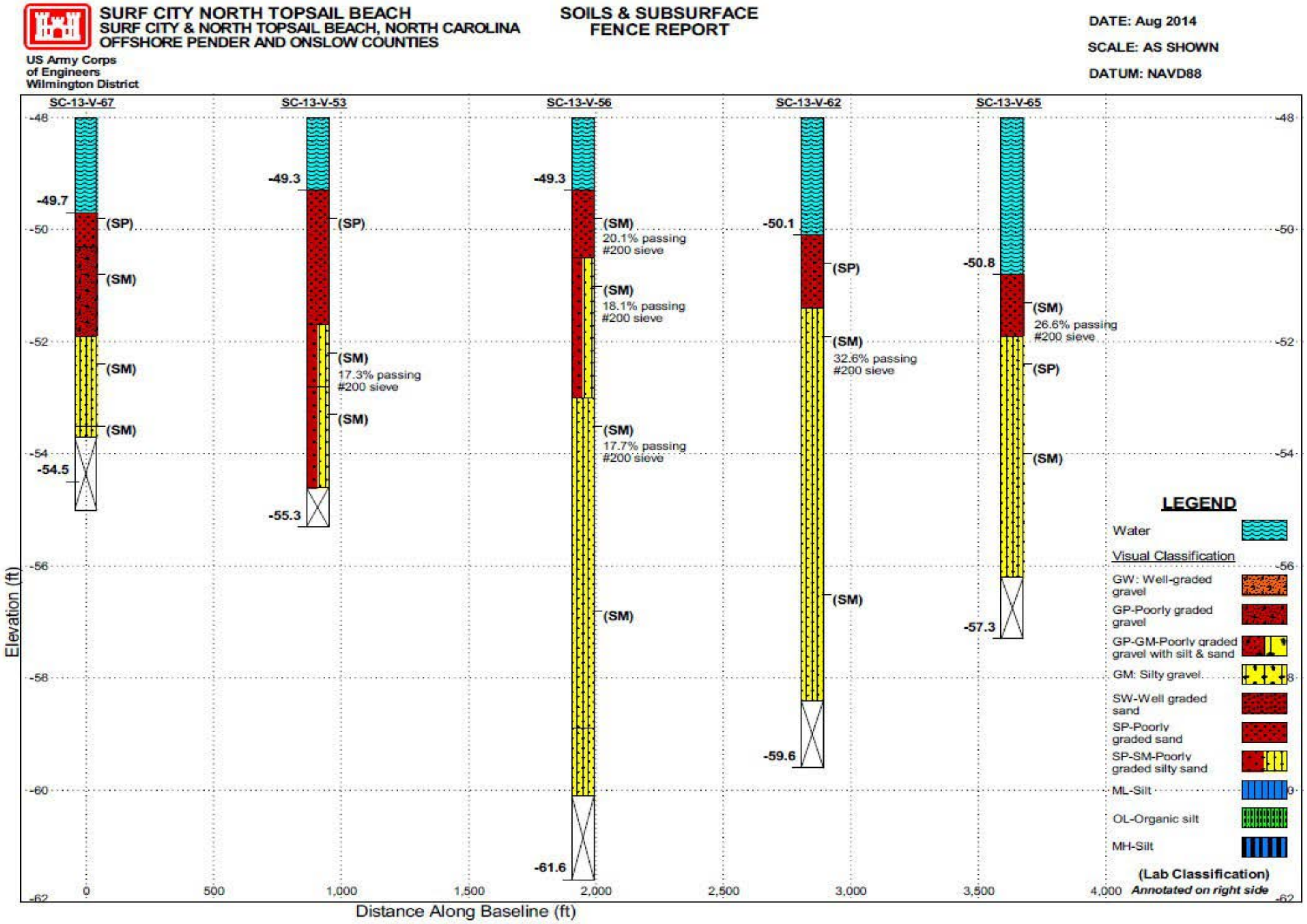


Figure 14. 2-D geologic cross section in Borrow Area E, profile E2. Bearing S to N.

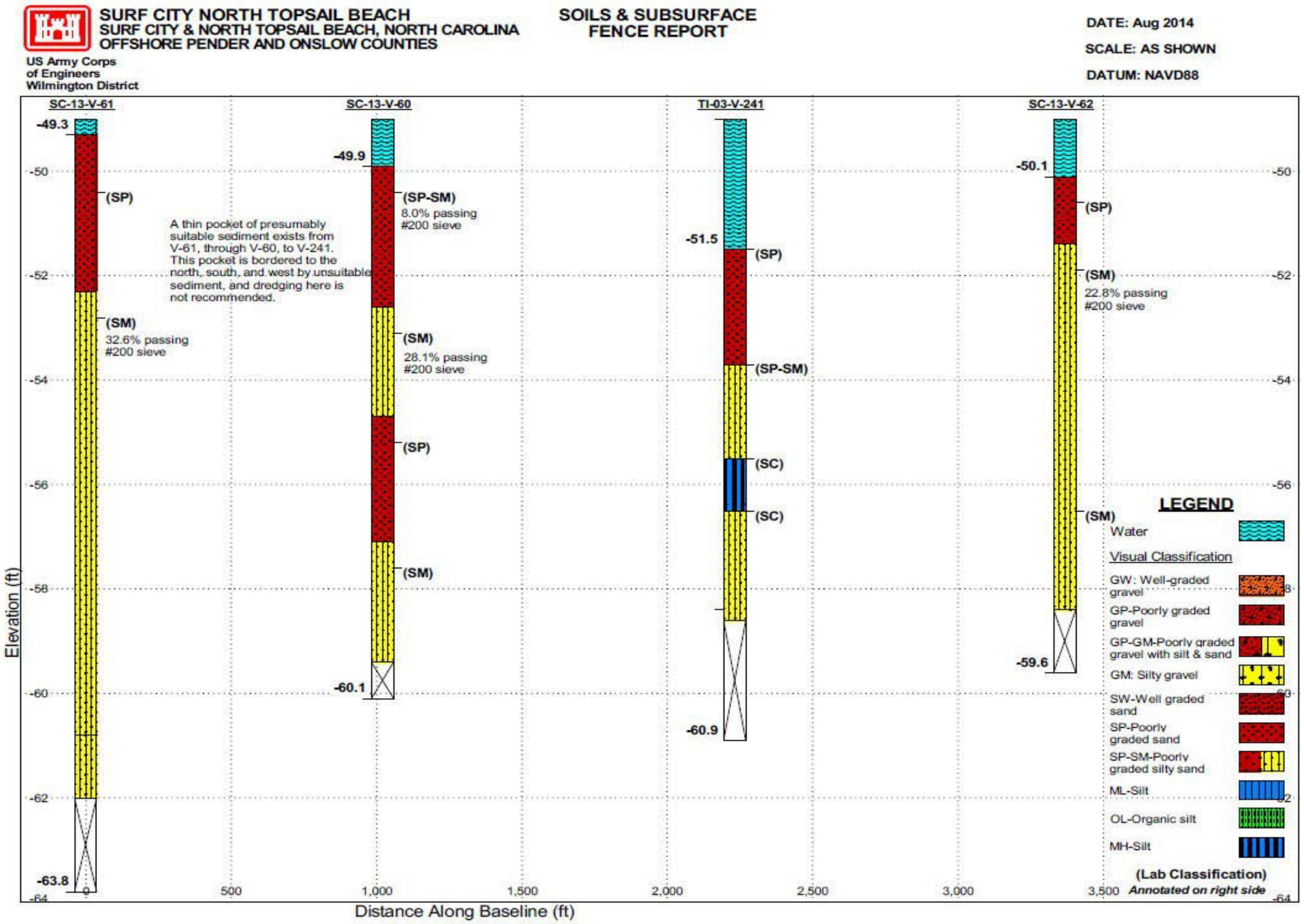


Figure 15. 2-D geologic cross section in Borrow Area E, profile E3. Bearing W to E.

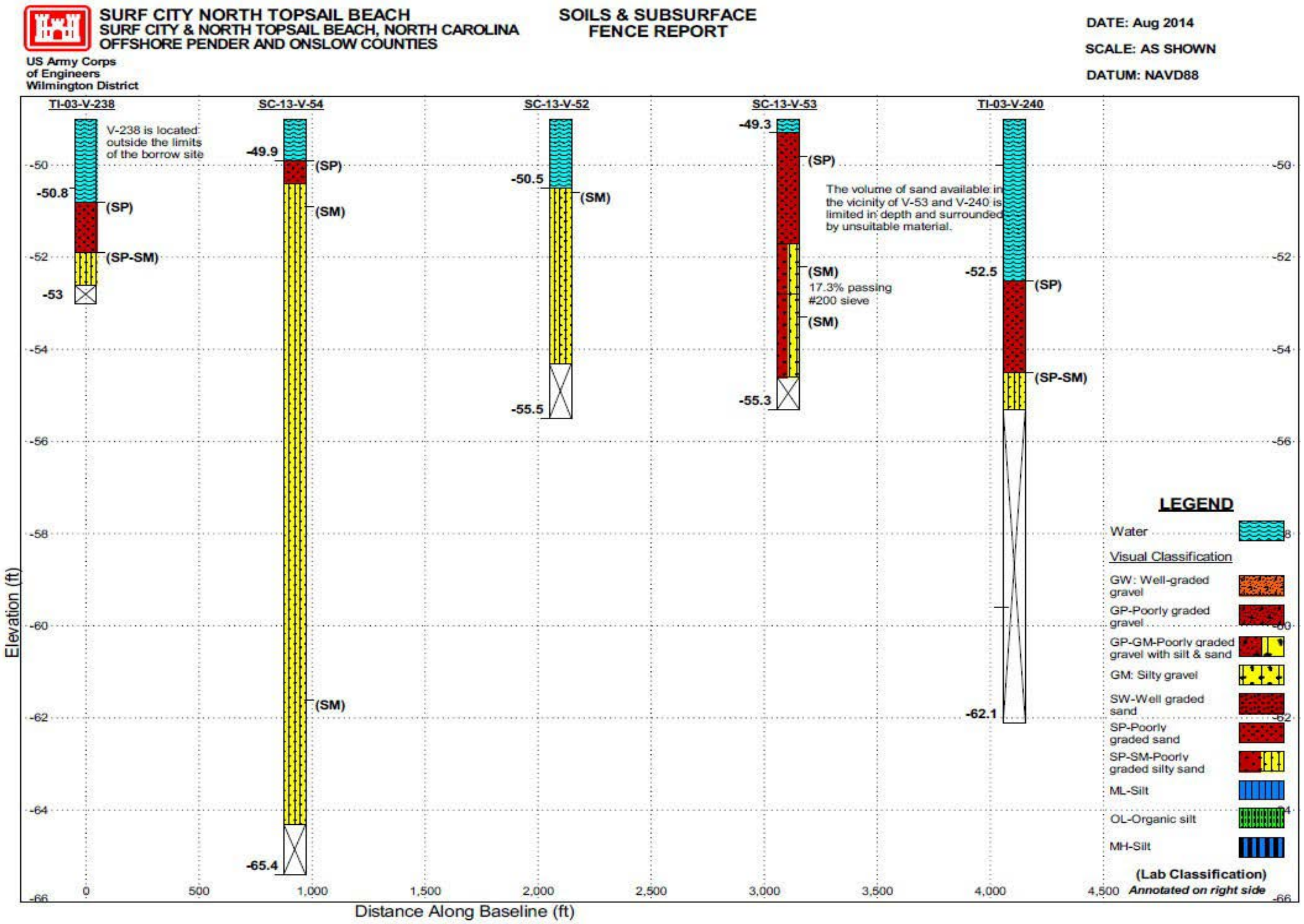


Figure 16. 2-D geologic cross section in Borrow Area E, profile E4. Bearing W to E.

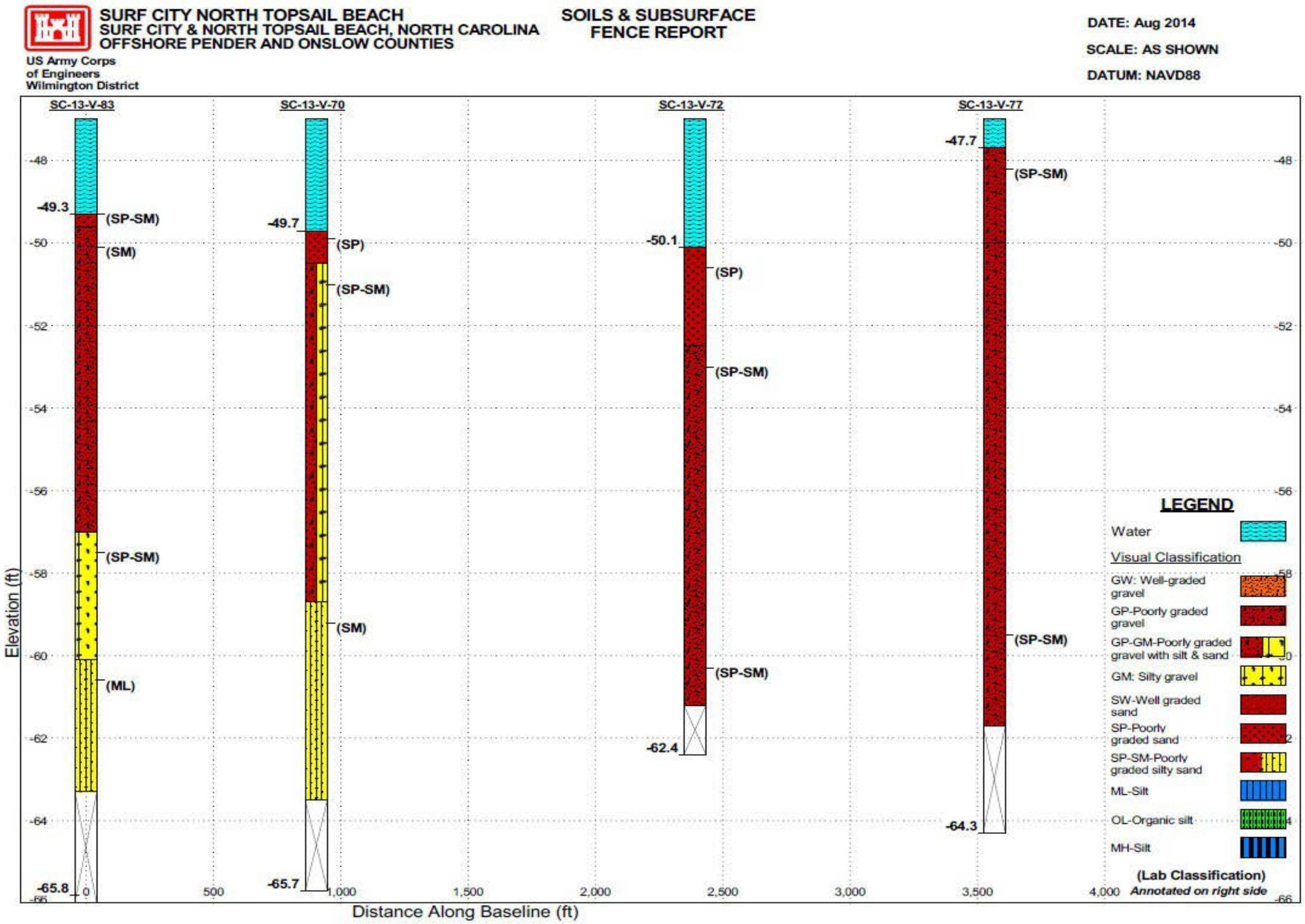


Figure 17. 2-D geologic cross section in Borrow Area F, profile F1. Bearing NW to SE.

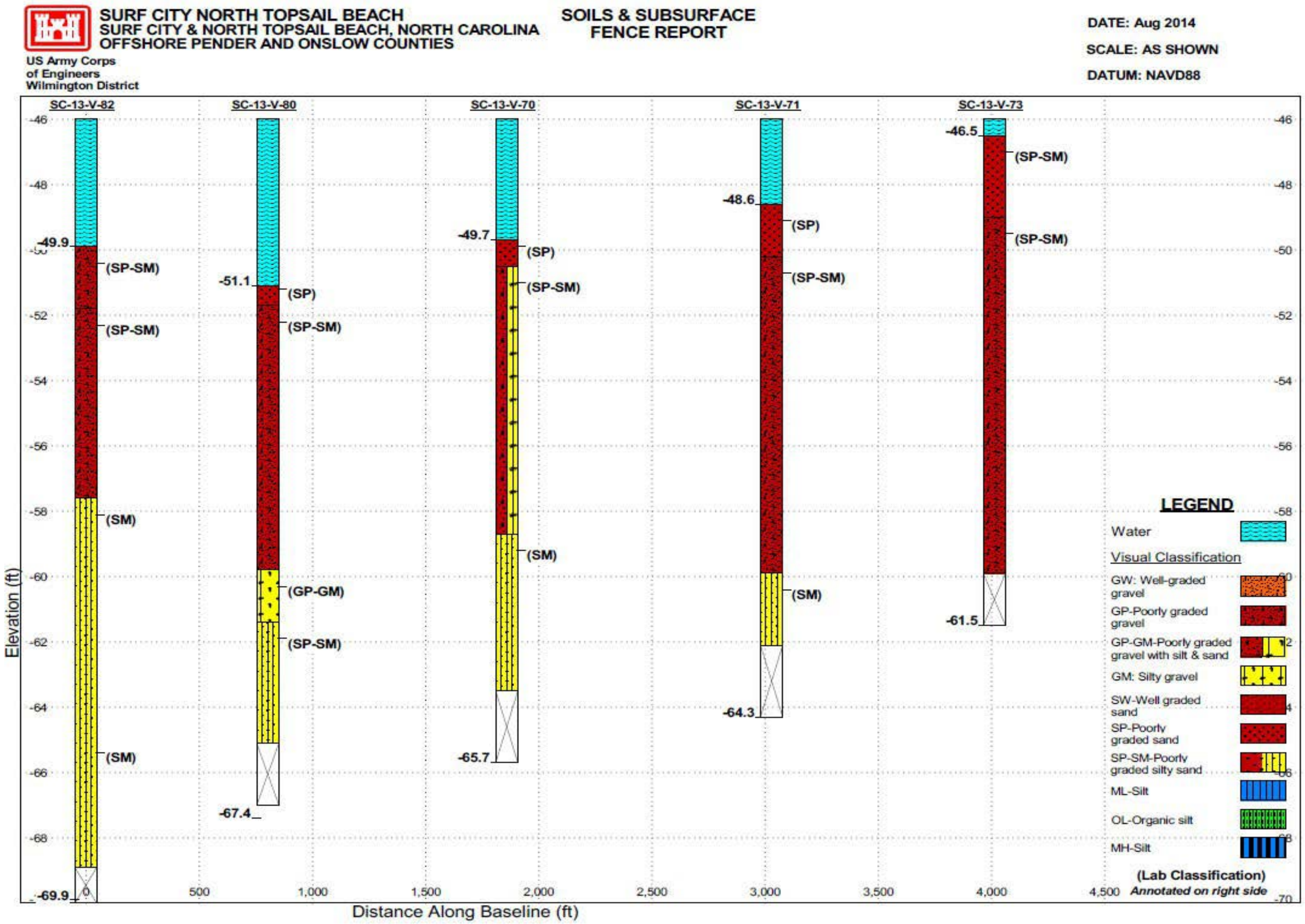


Figure 18. 2-D geologic cross section in Borrow Area F, profile F2. Bearing SW to NE.

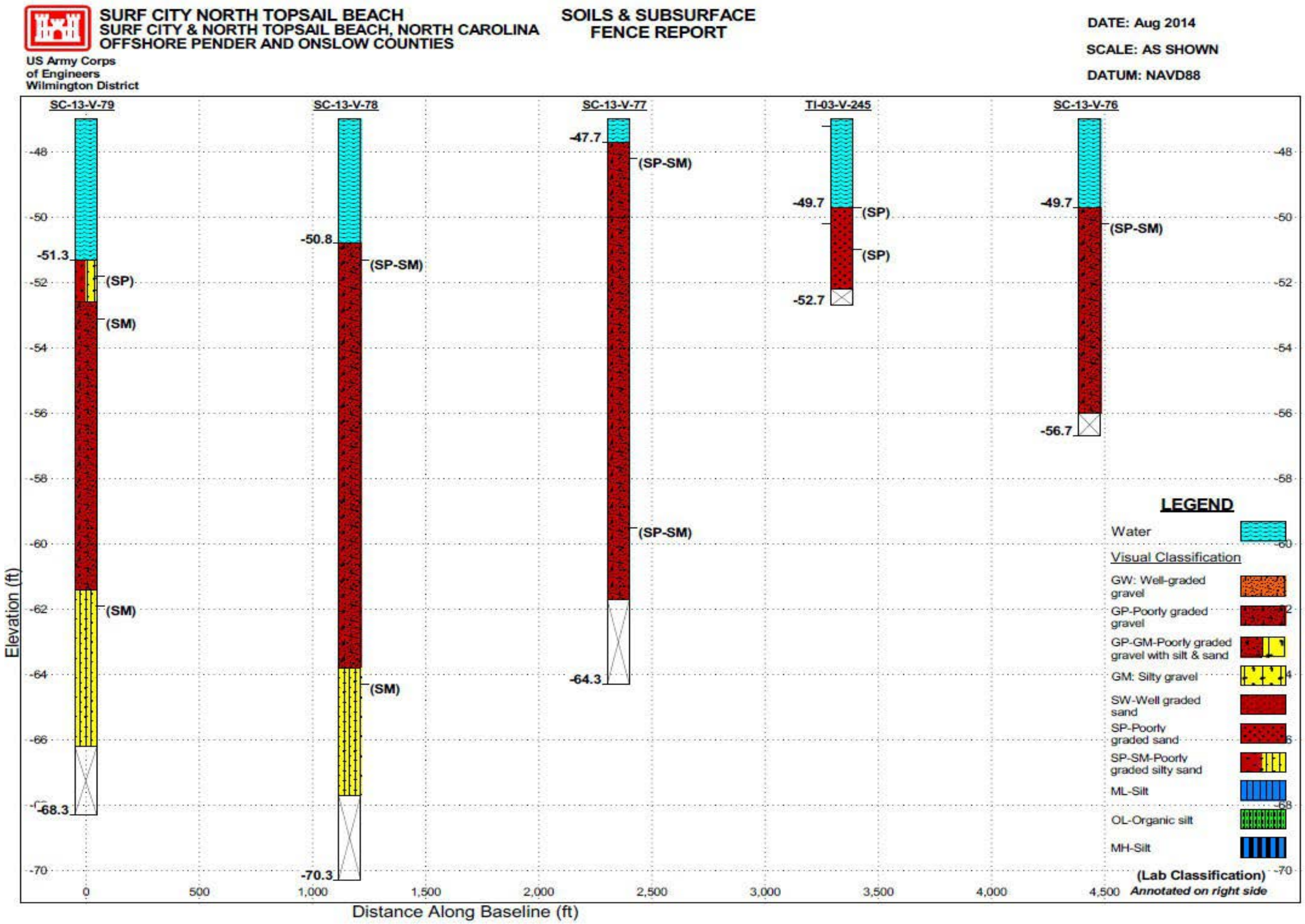


Figure 19. 2-D geologic cross section in Borrow Area F, profile F3. Bearing SW to NE.

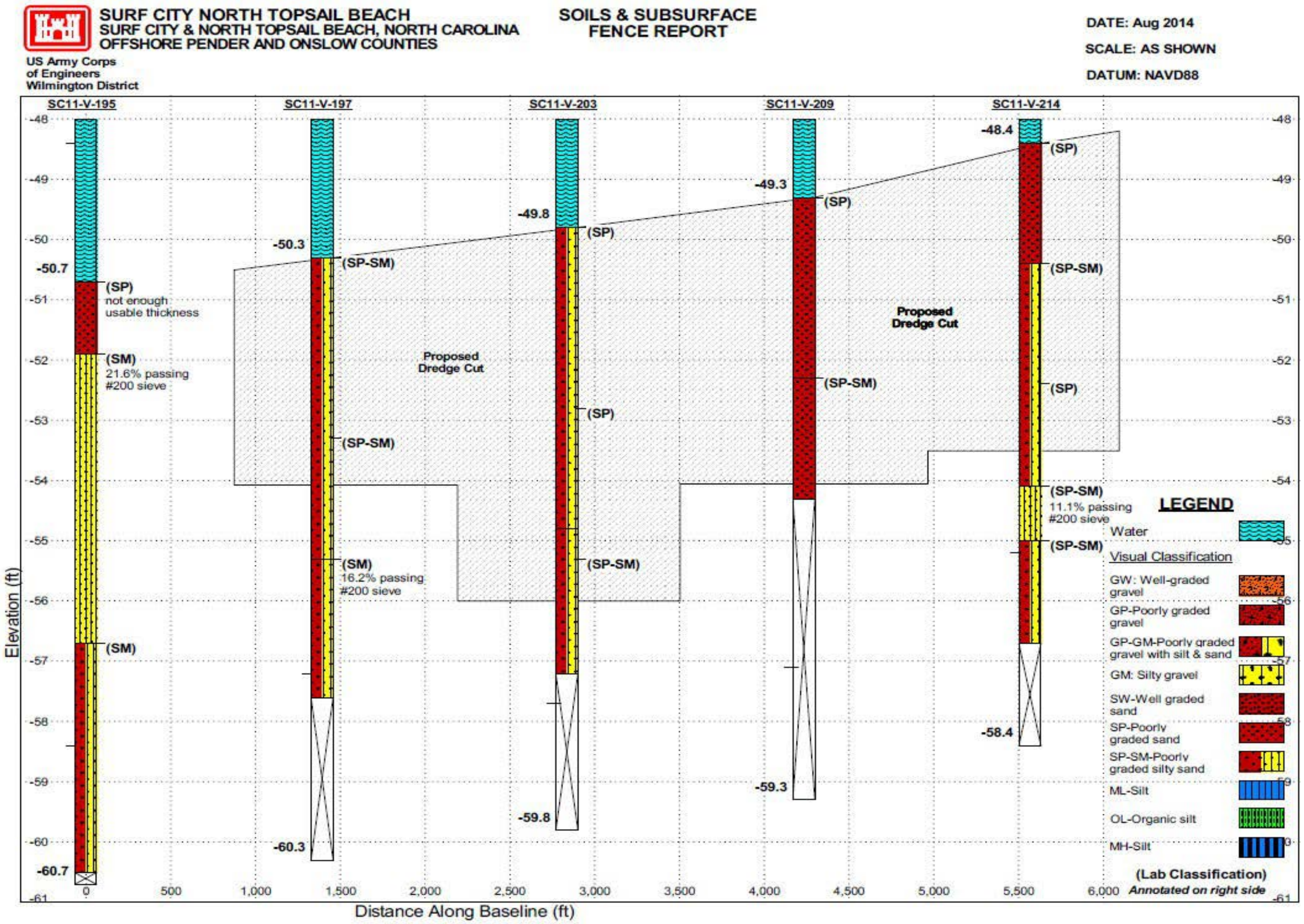


Figure 20. 2-D geologic cross section in Borrow Area G, profile G1. Bearing S to N.

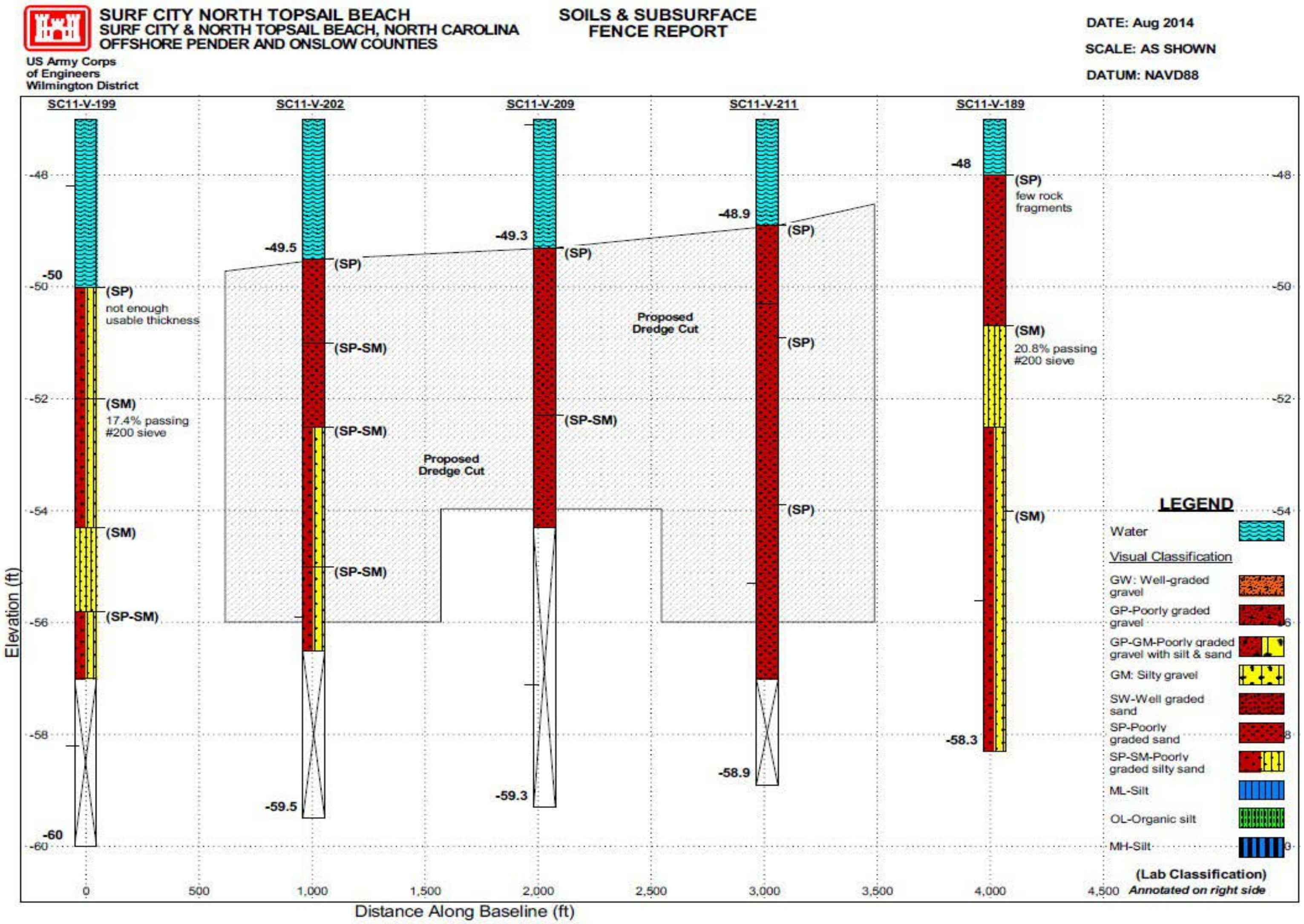


Figure 21. 2-D geologic cross section in Borrow Area G, profile G2. Bearing SW to NE.

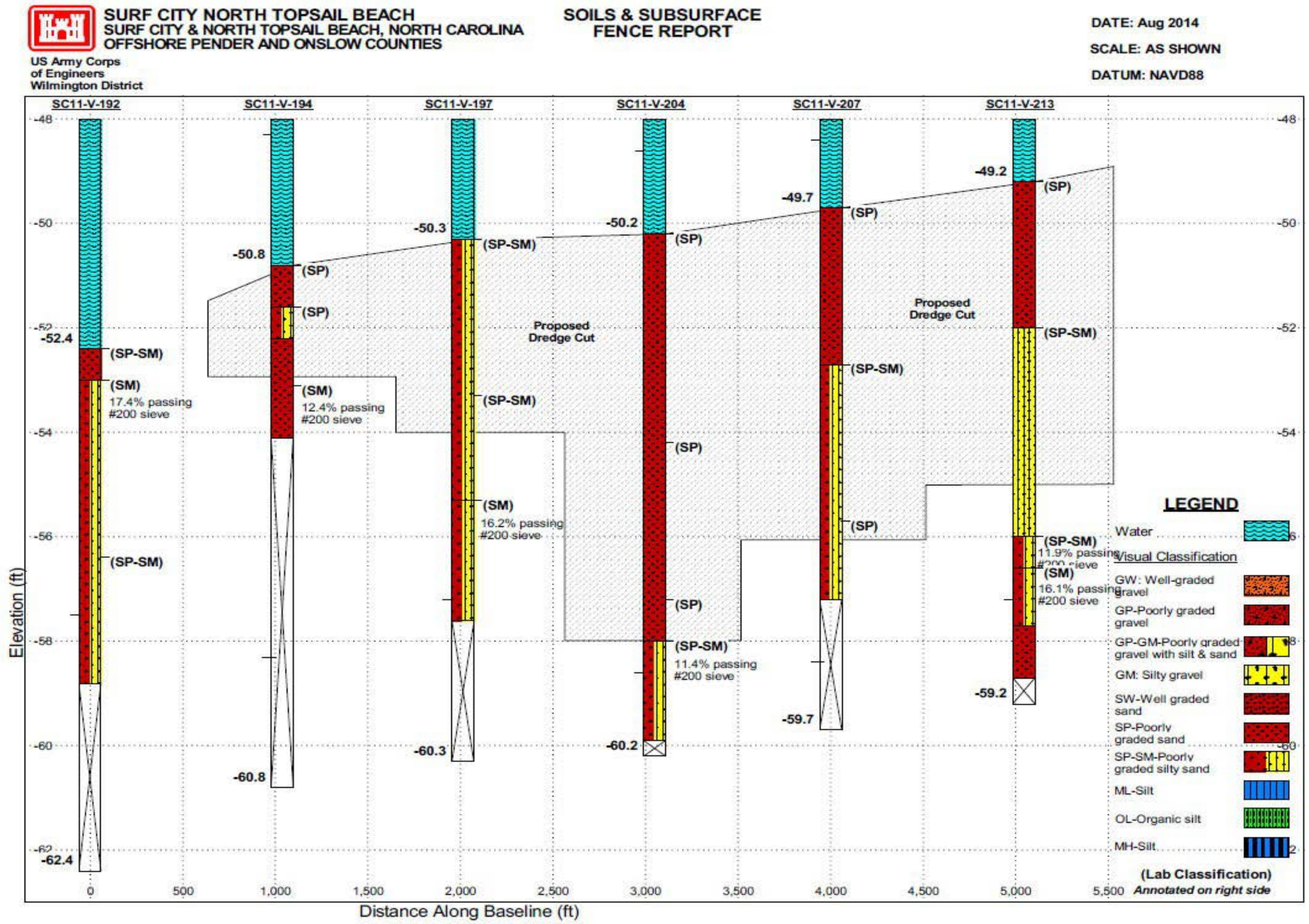


Figure 22. 2-D geologic cross section in Borrow Area G, profile G3. Bearing SW to NE.

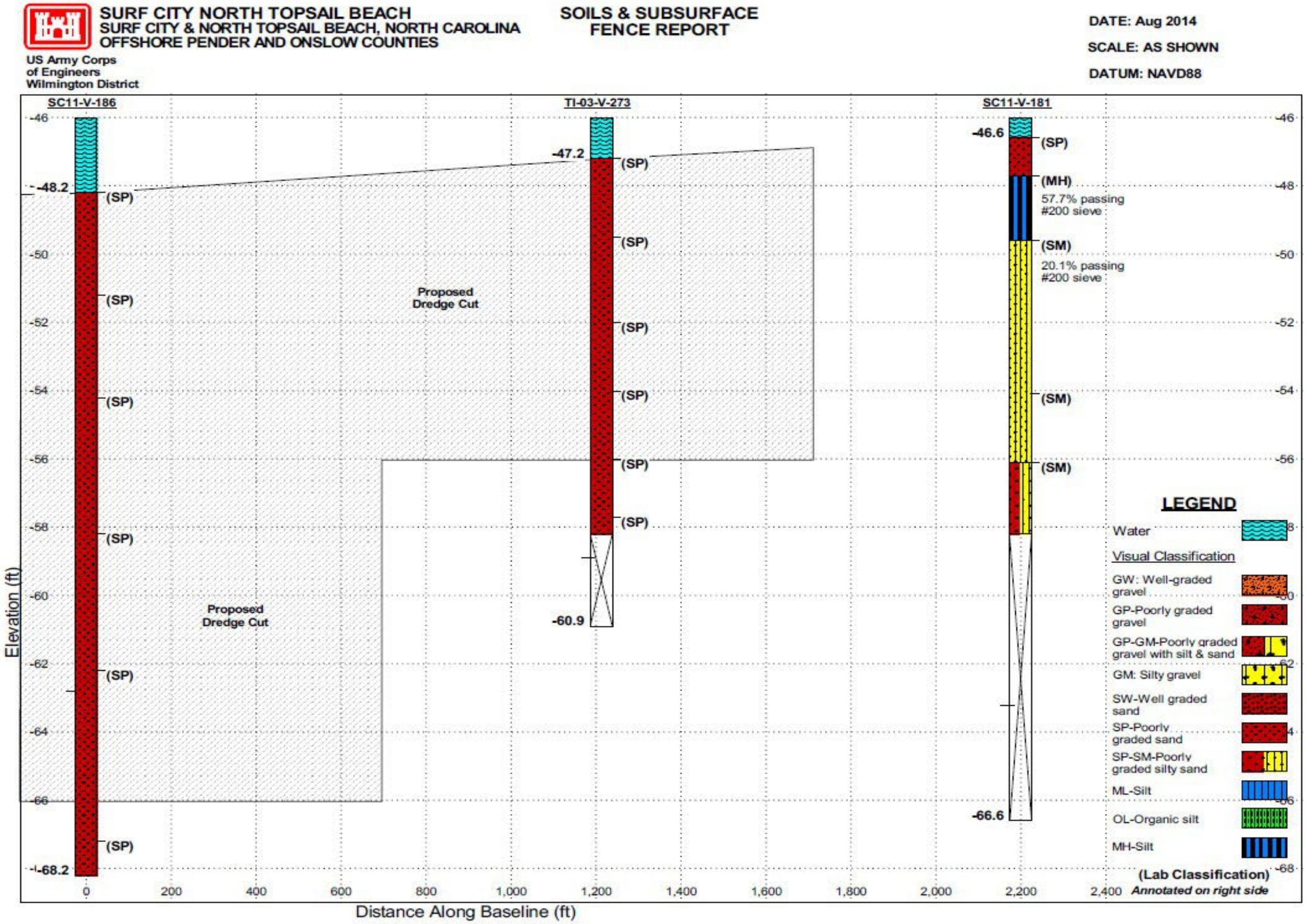


Figure 23. 2-D geologic cross section in Borrow Area H, profile H1. Bearing S to N.

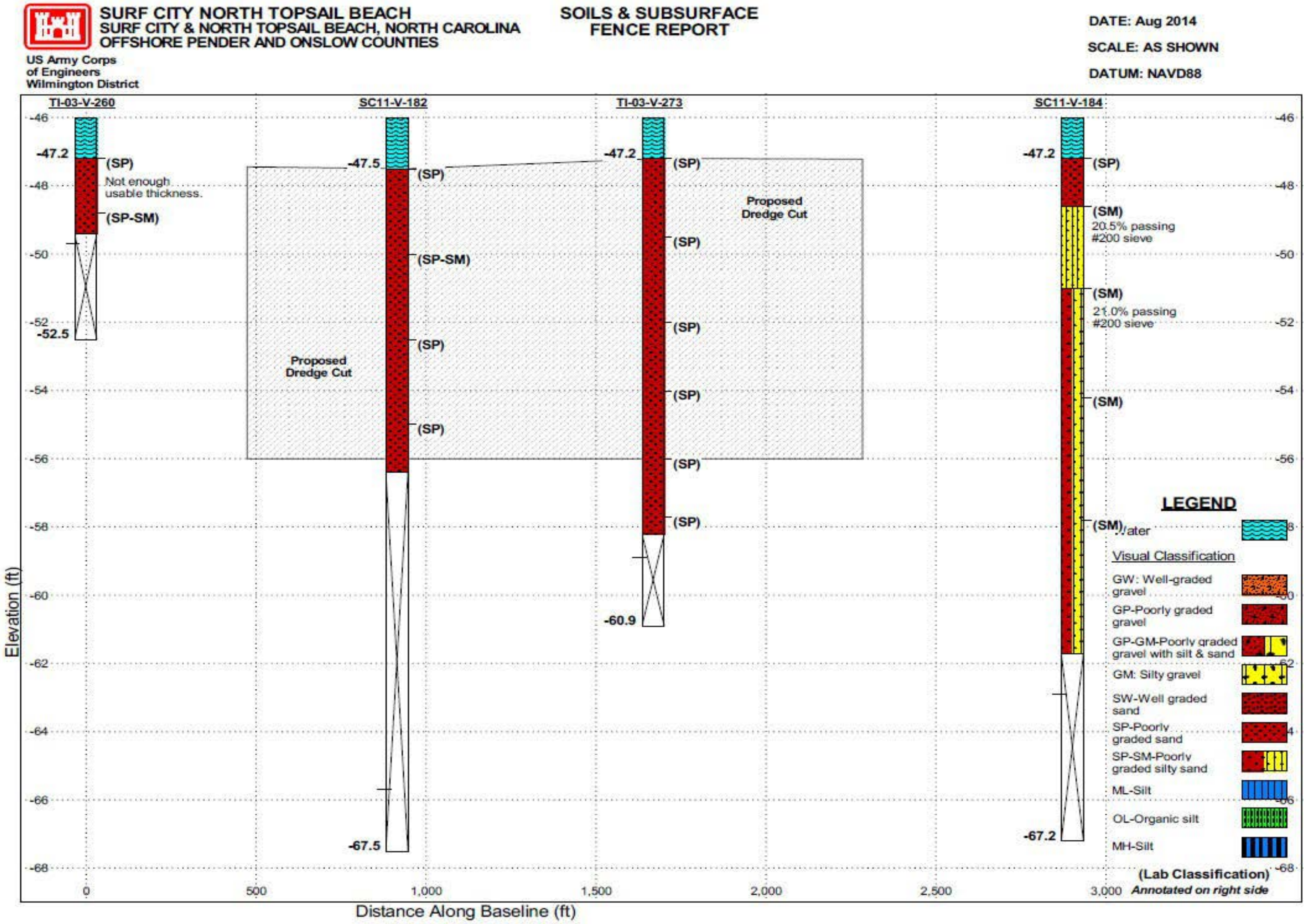


Figure 24. 2-D geologic cross section in Borrow Area H, profile H2. Bearing SW to NE.

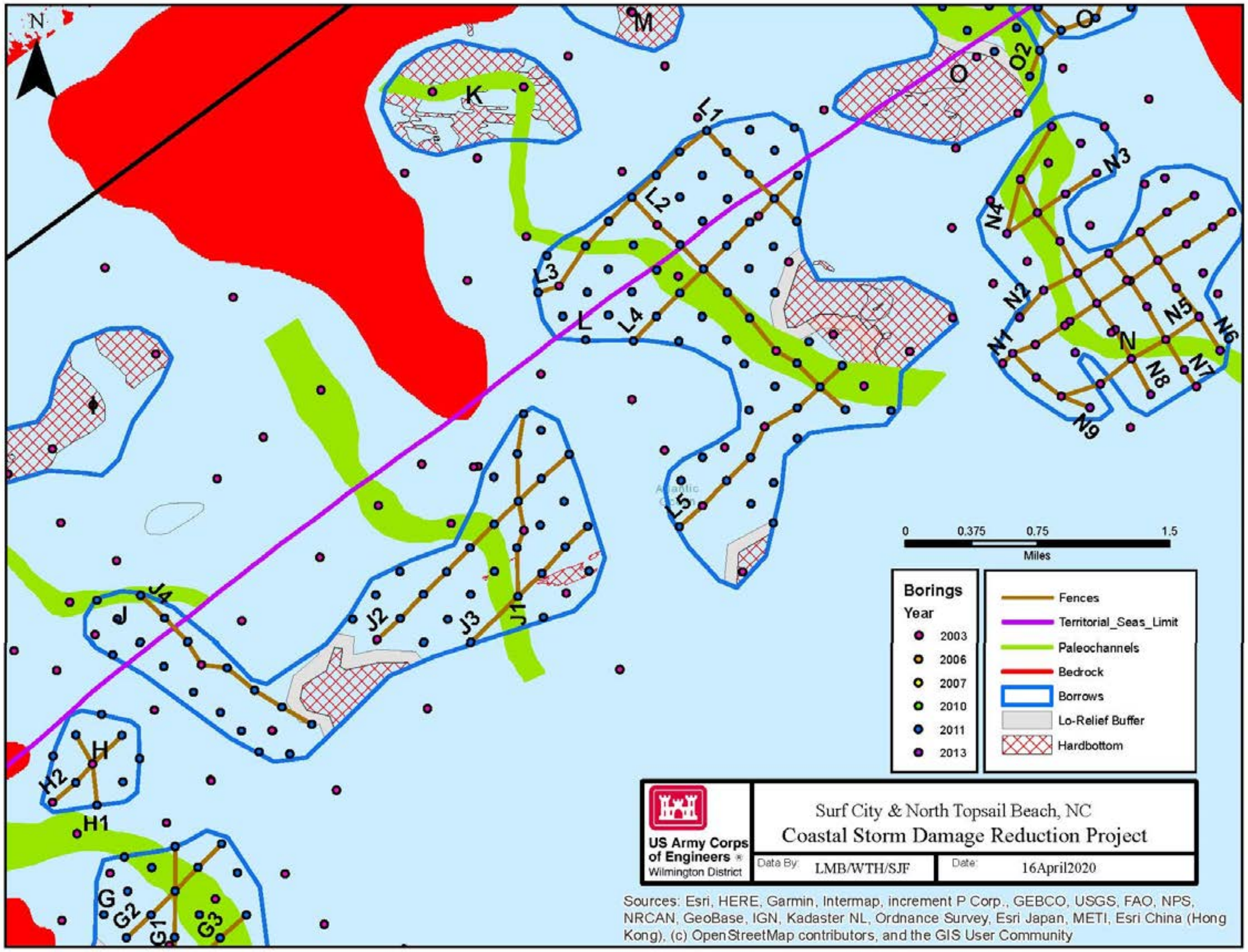


Figure 25. Geographic location of Fence Diagrams for Borrow Areas J-L.

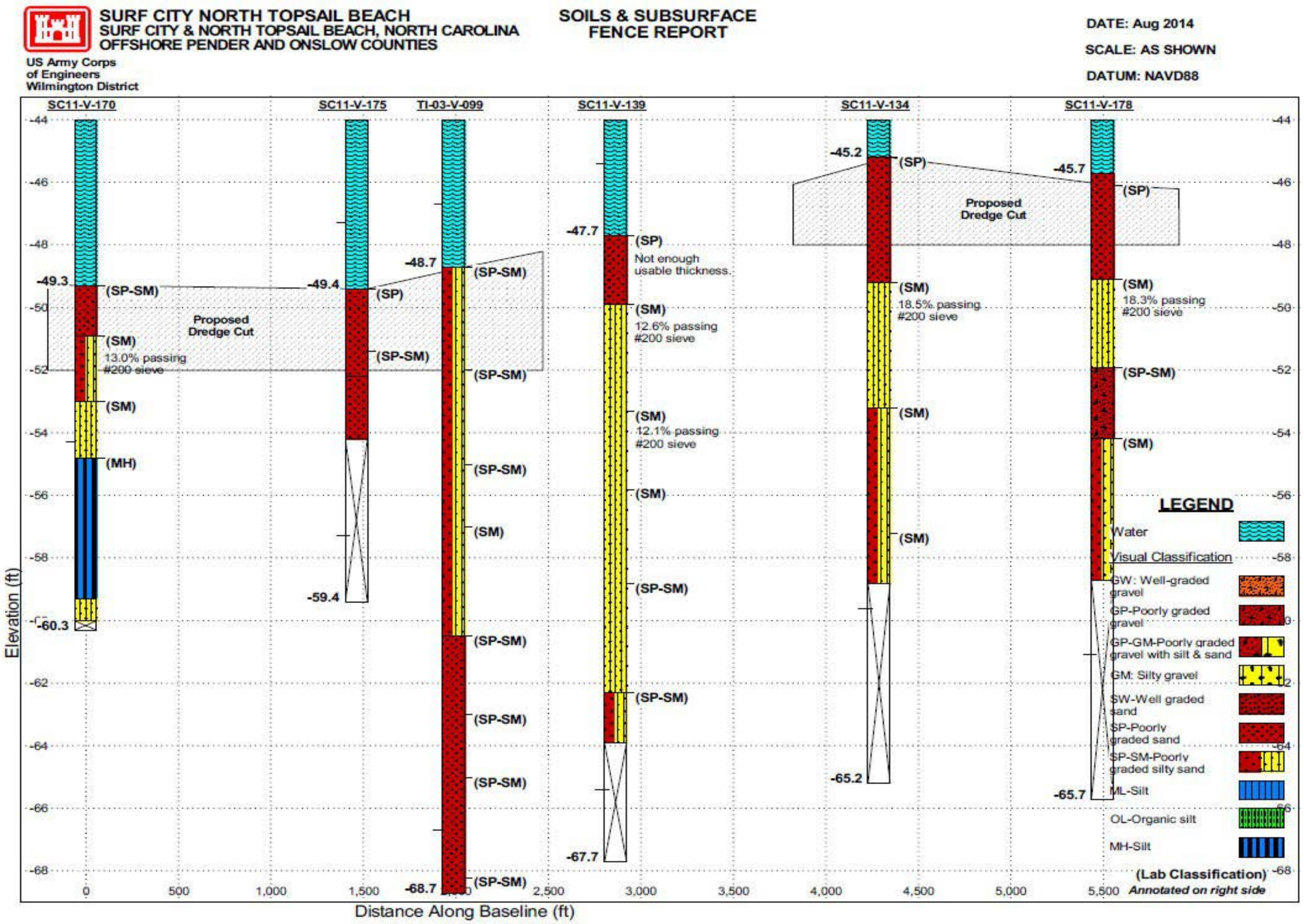


Figure 26. 2-D geologic cross section in Borrow Area J, profile J1. Bearing N to S.

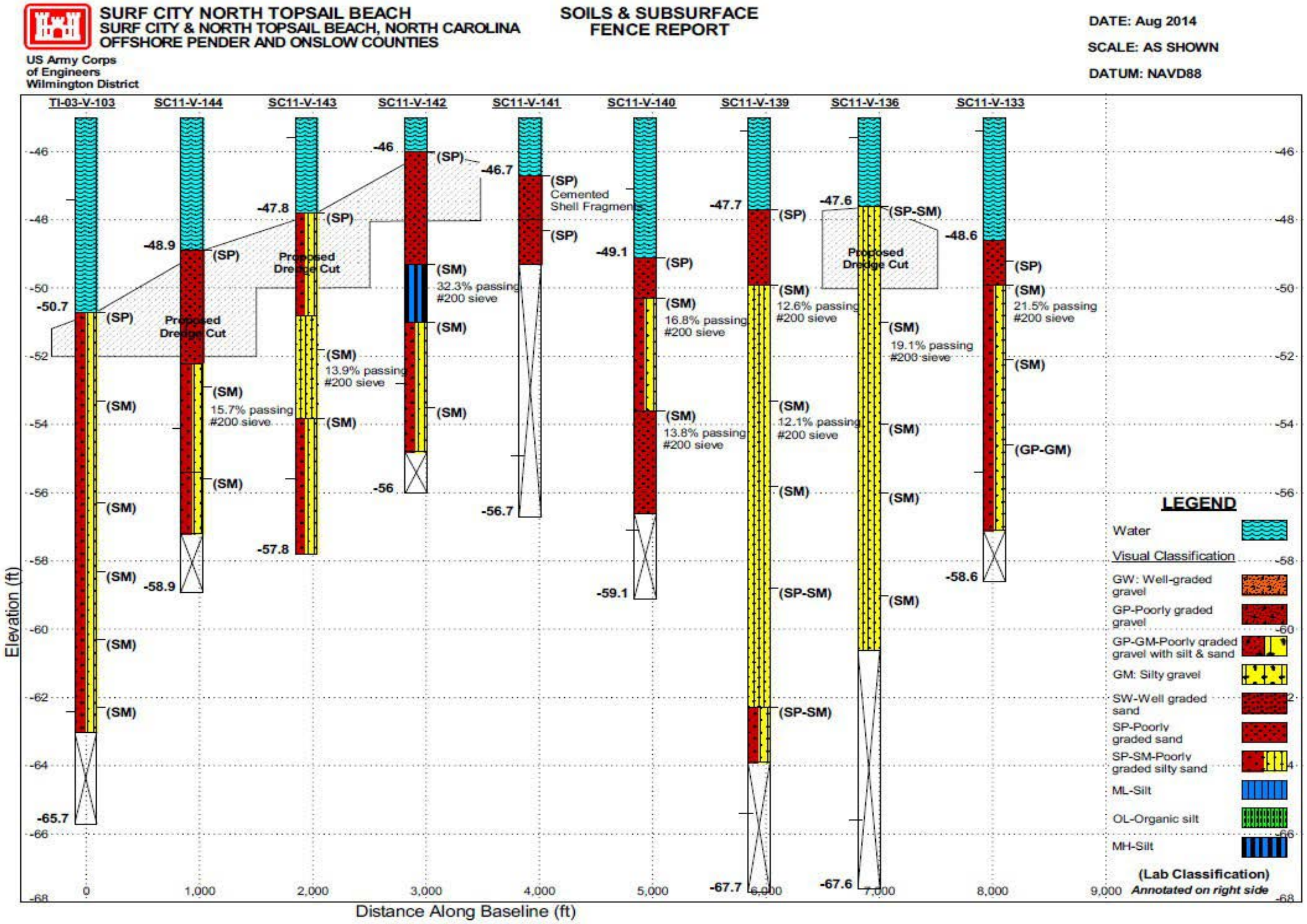


Figure 27. 2-D geologic cross section in Borrow Area J, profile J2. Bearing SW to NE.

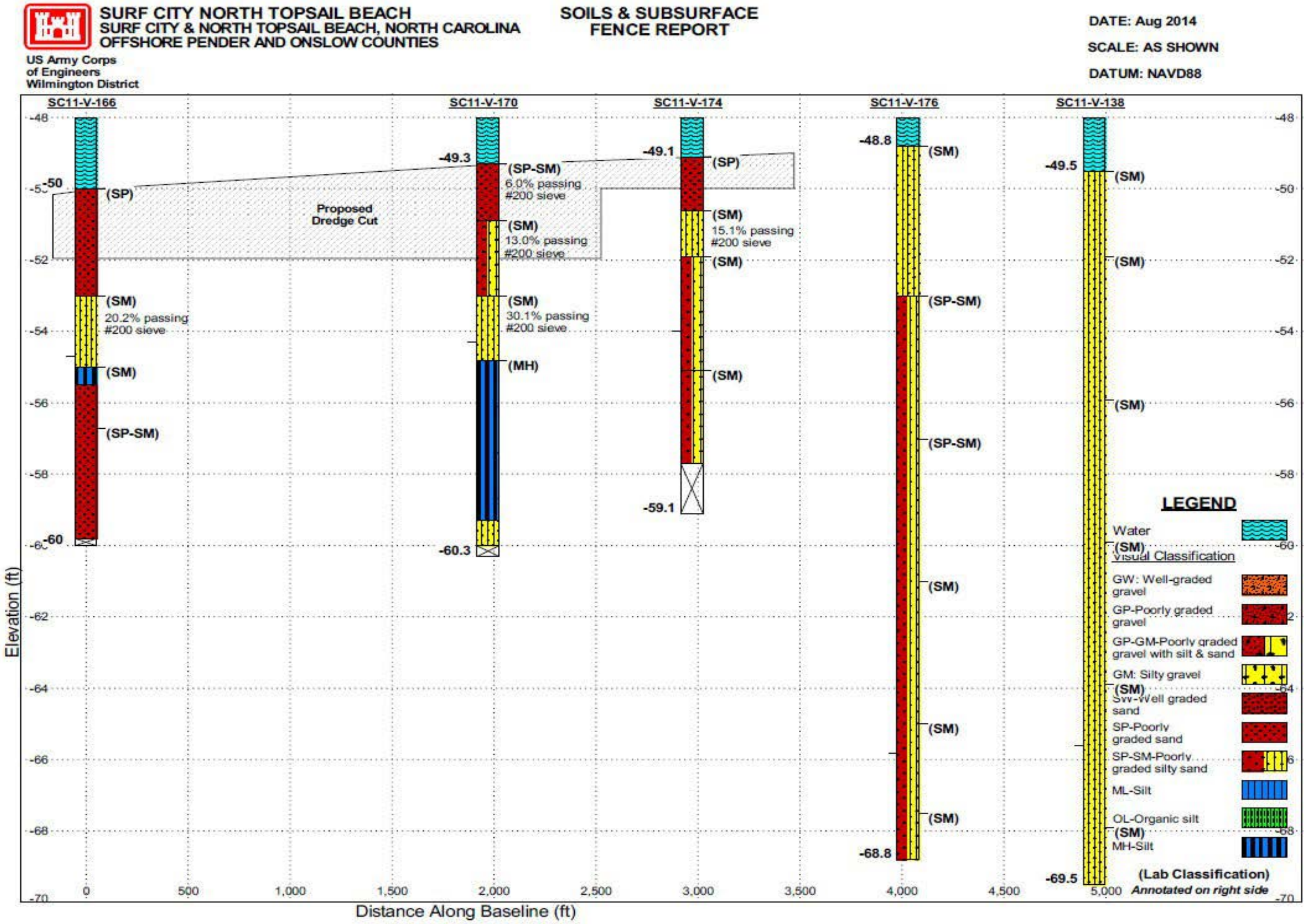


Figure 28. 2-D geologic cross section in Borrow Area J, profile J3. Bearing SW to NE.

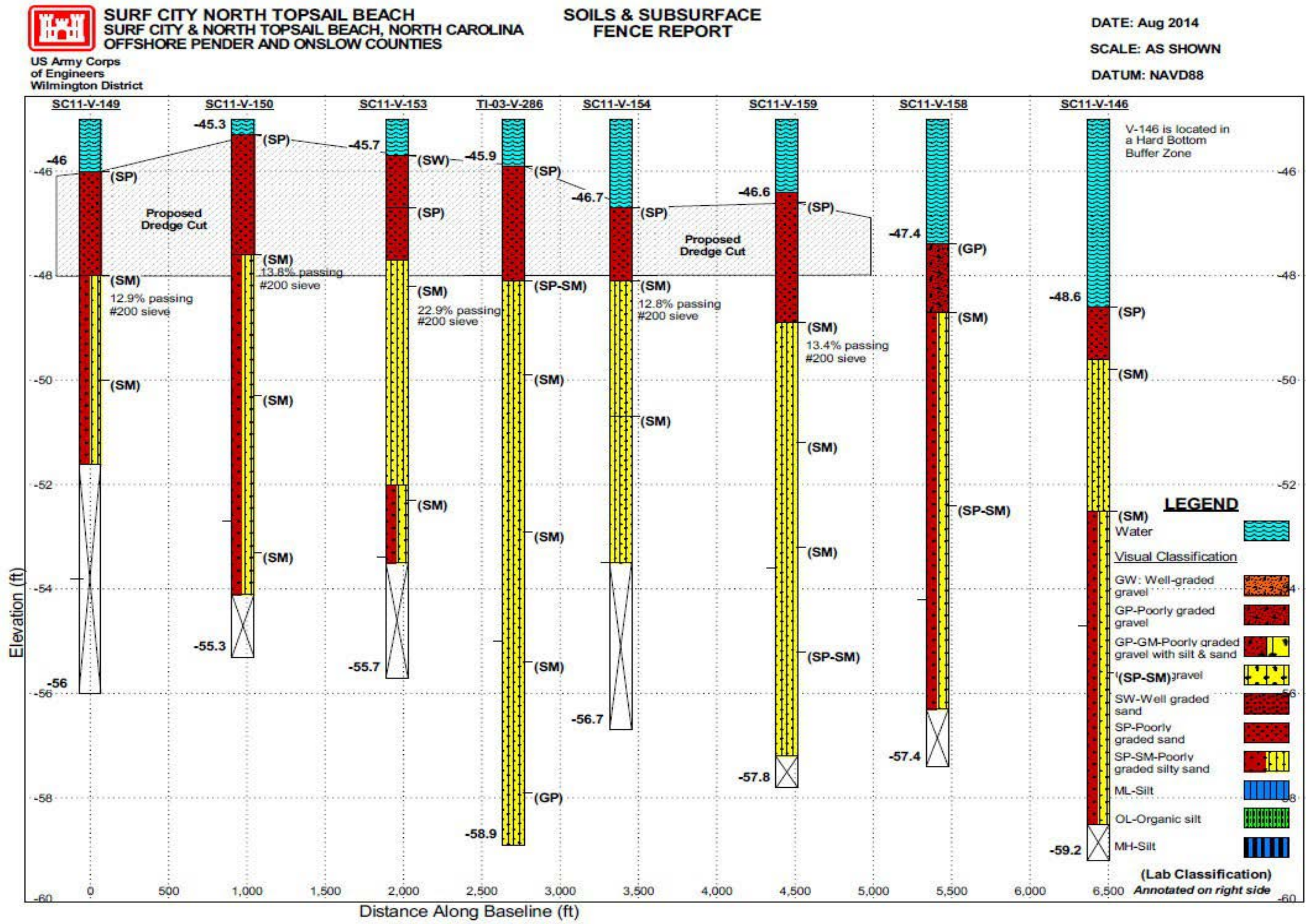


Figure 29. 2-D geologic cross section in Borrow Area J, profile J4. Bearing NW to SE.

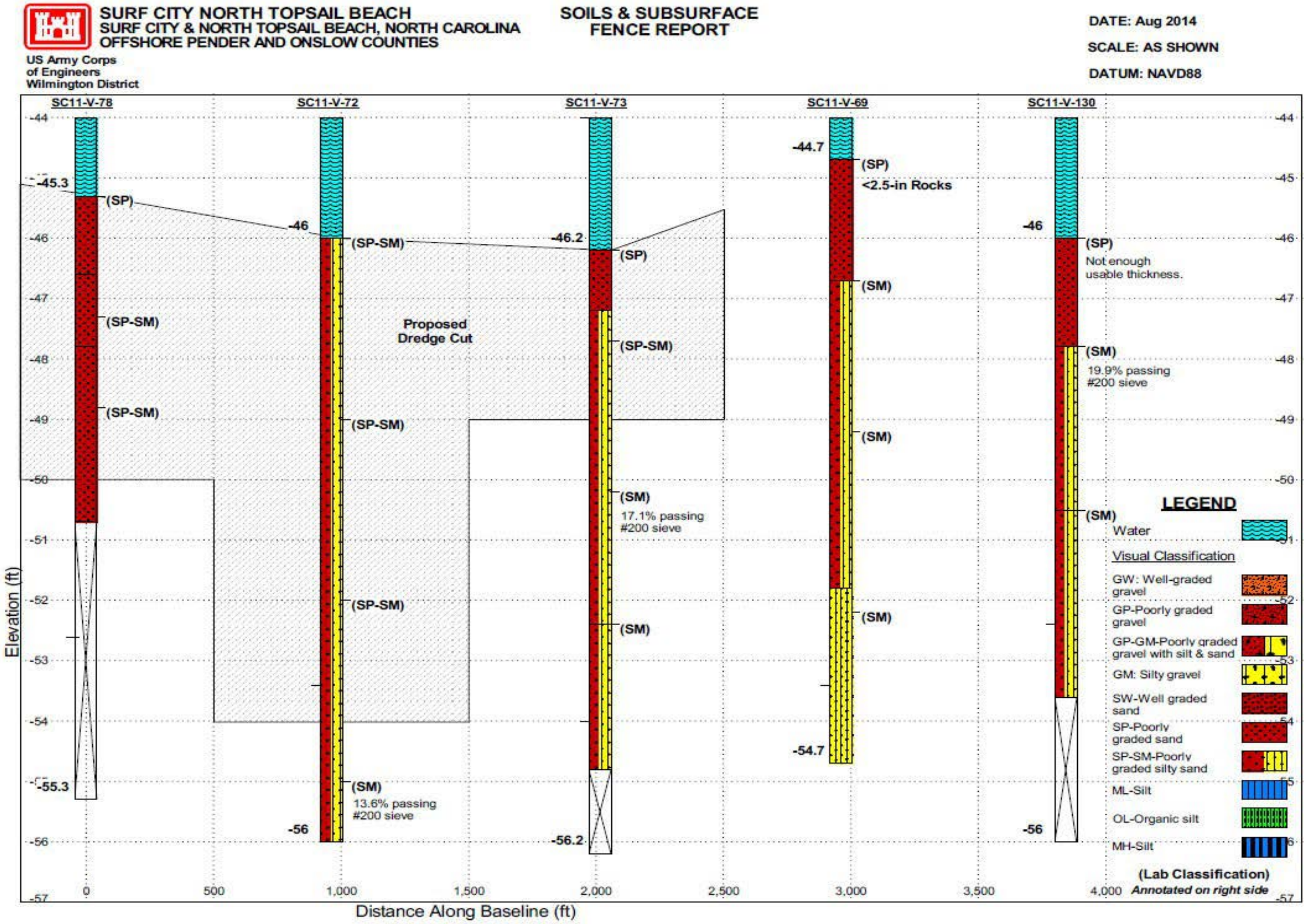


Figure 30. 2-D geologic cross section in Borrow Area L, profile L1. Bearing SE to NW.

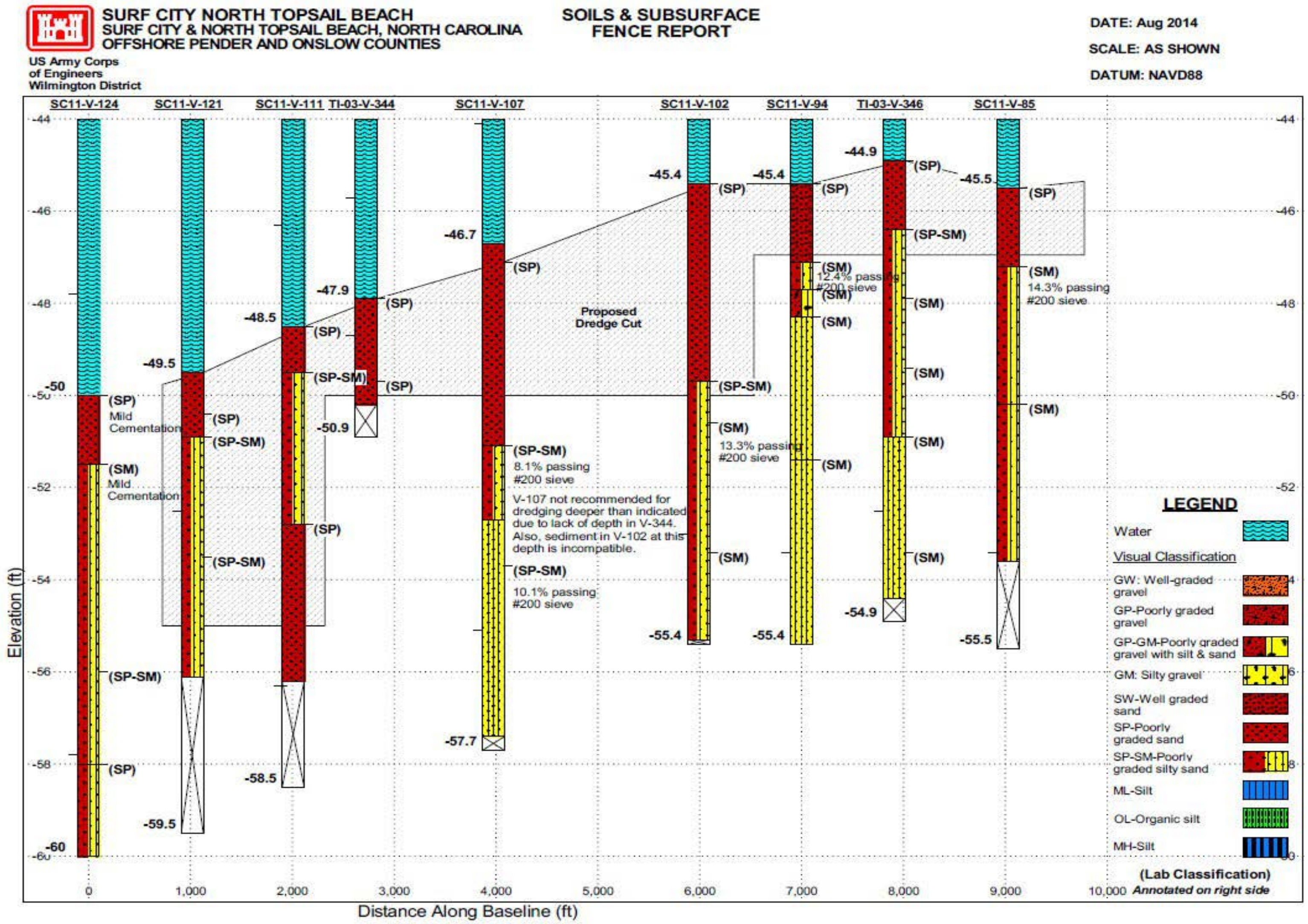


Figure 31. 2-D geologic cross section in Borrow Area L, profile L2. Bearing SE to NW.

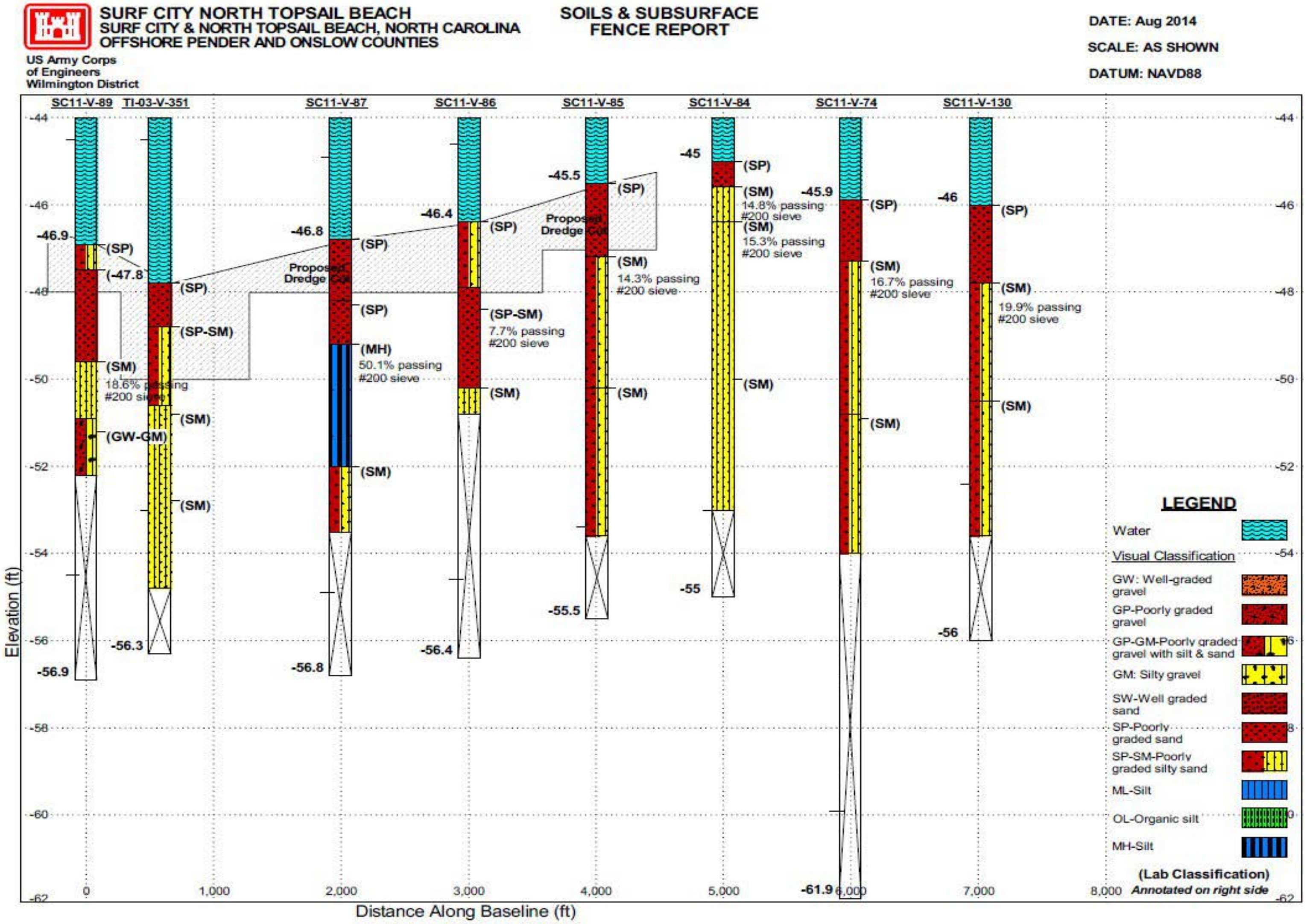


Figure 32. 2-D geologic cross section in Borrow Area L, profile L3. Bearing SW to NE.

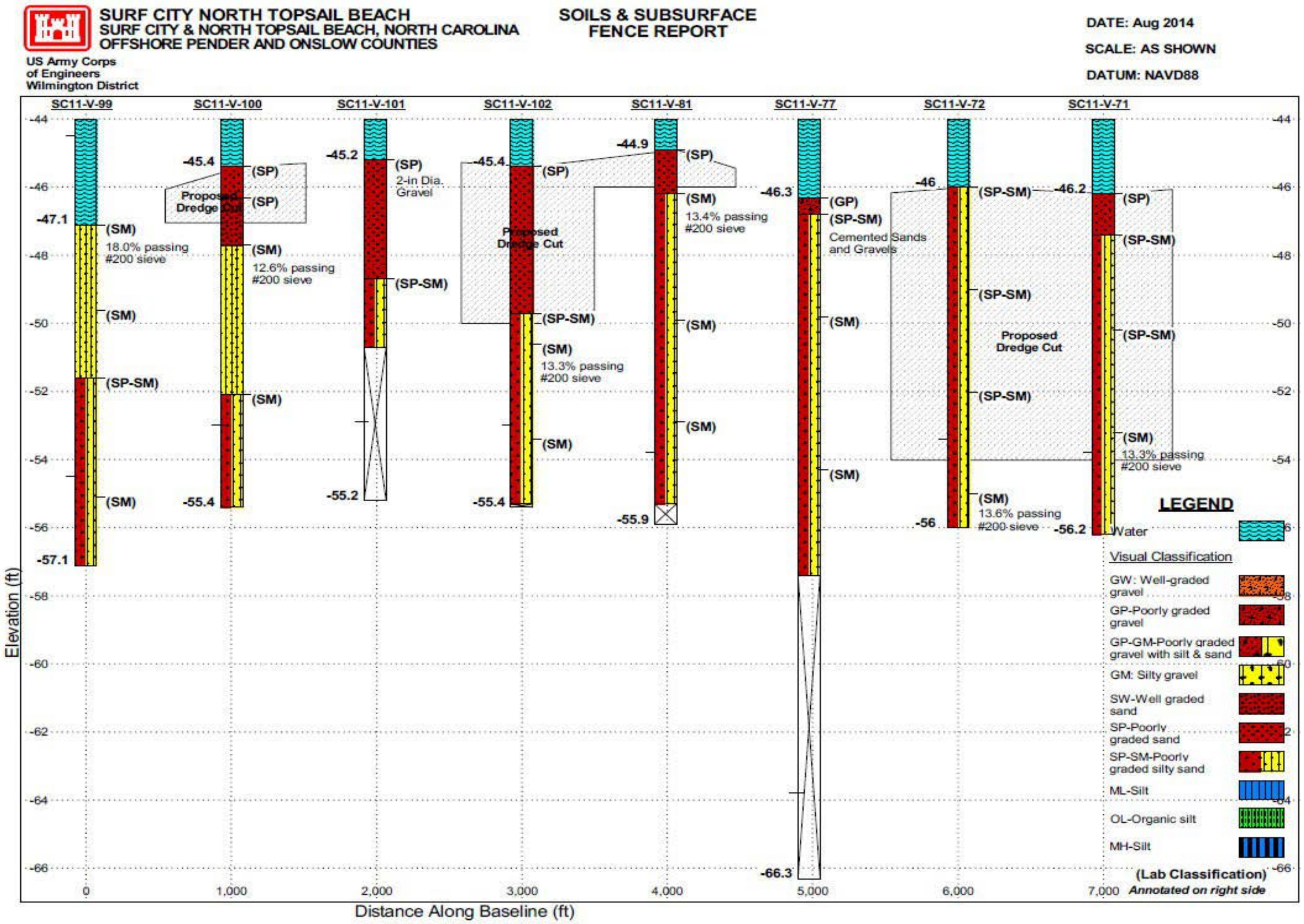


Figure 33. 2-D geologic cross section in Borrow Area L, profile L4. Bearing SW to NE.

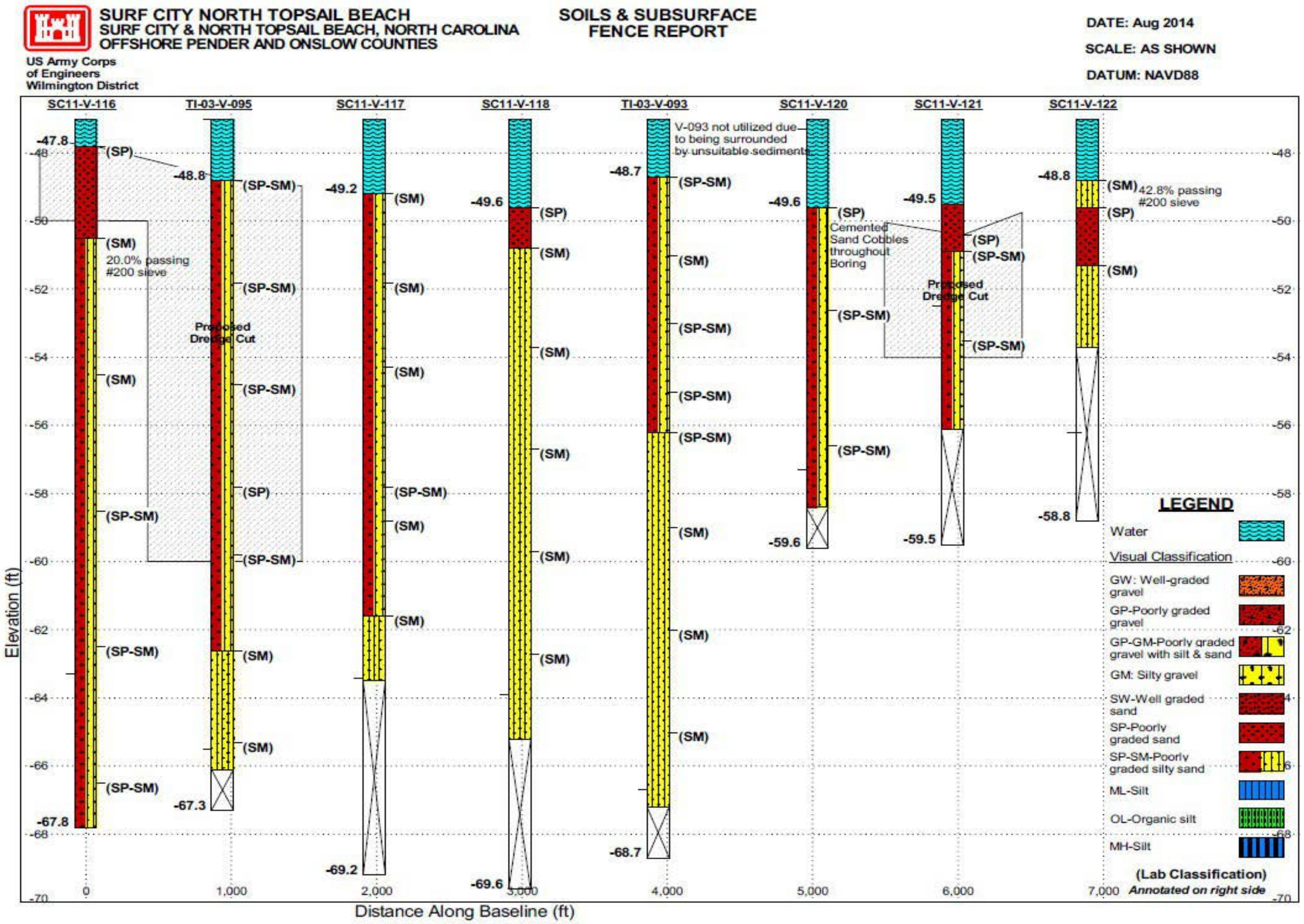


Figure 34. 2-D geologic cross section in Borrow Area L, profile L5. Bearing SW to NE.

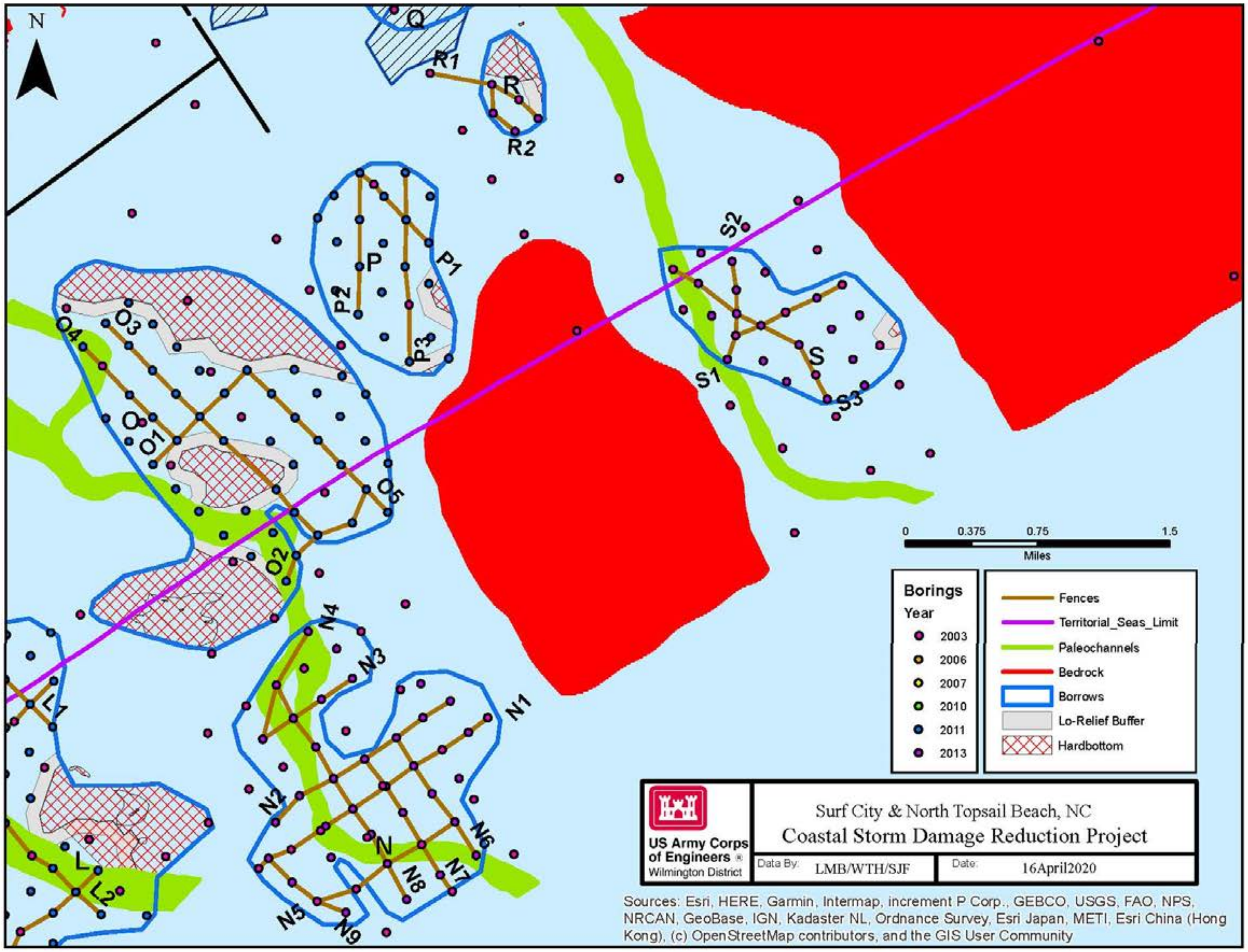


Figure 35. Geographic location of Fence Diagrams for Borrow Areas N-S.

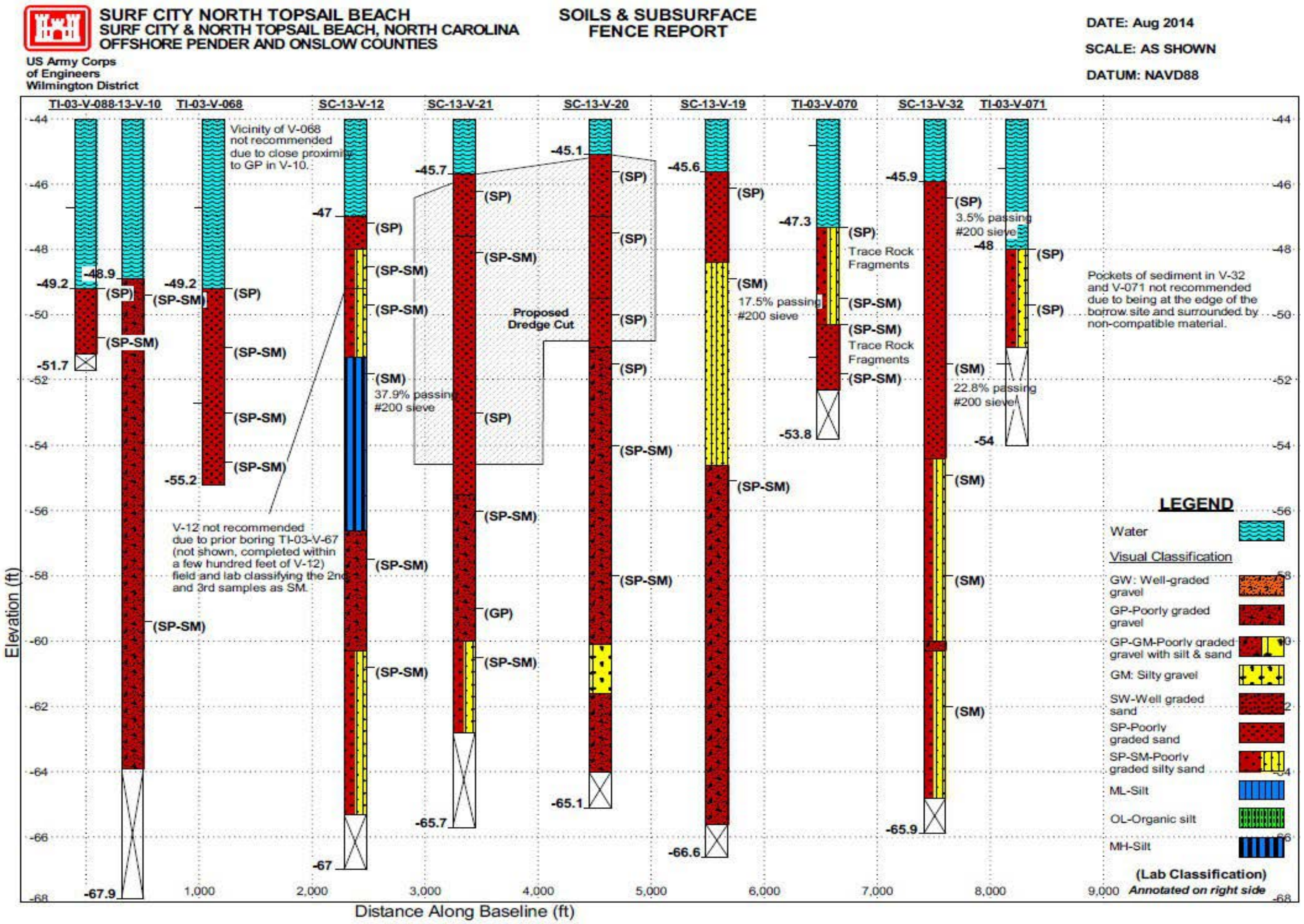


Figure 36. 2-D geologic cross section in Borrow Area N, profile N1. Bearing SW to NE.

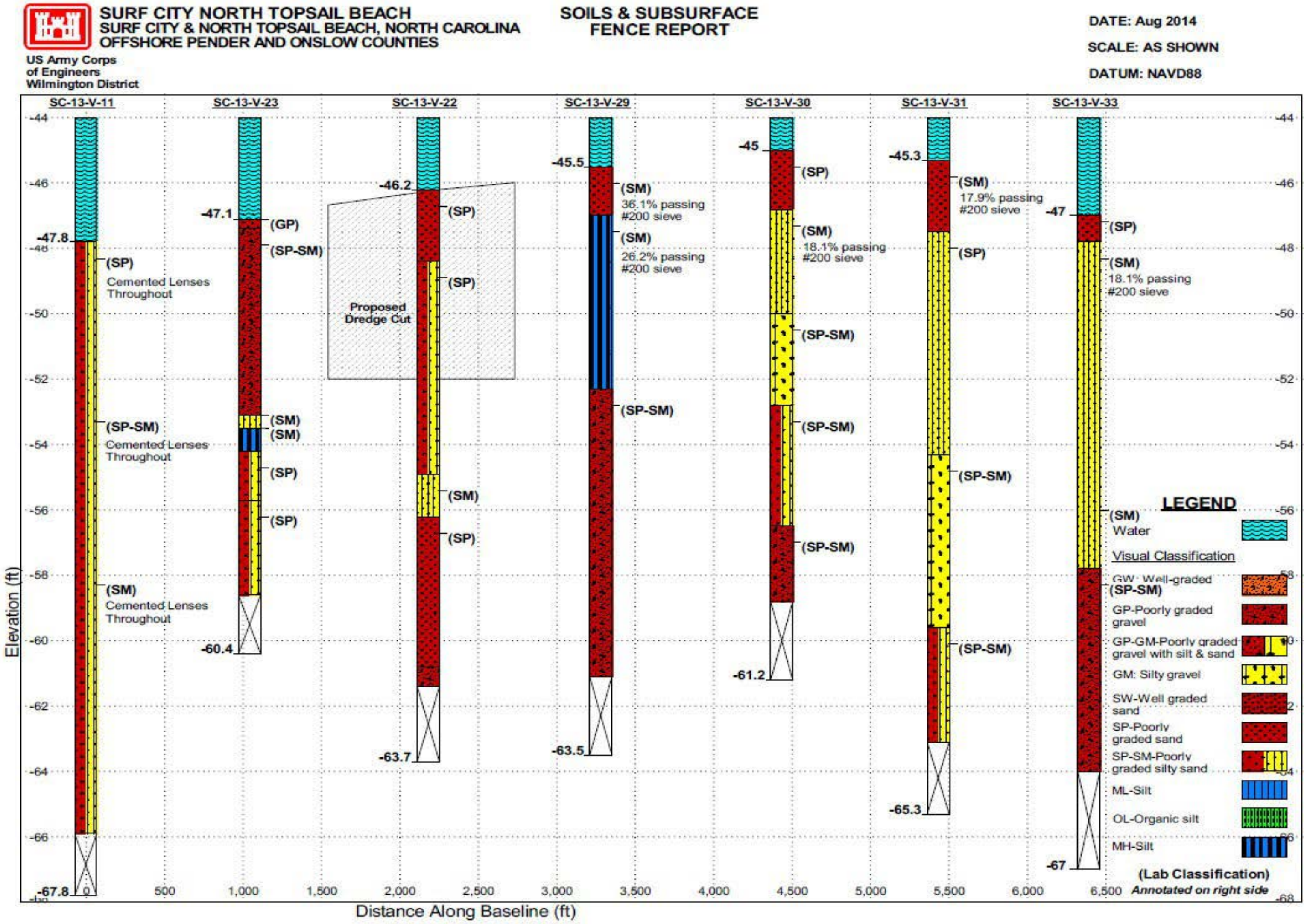


Figure 37. 2-D geologic cross section in Borrow Area N, profile N2. Bearing SW to NE.

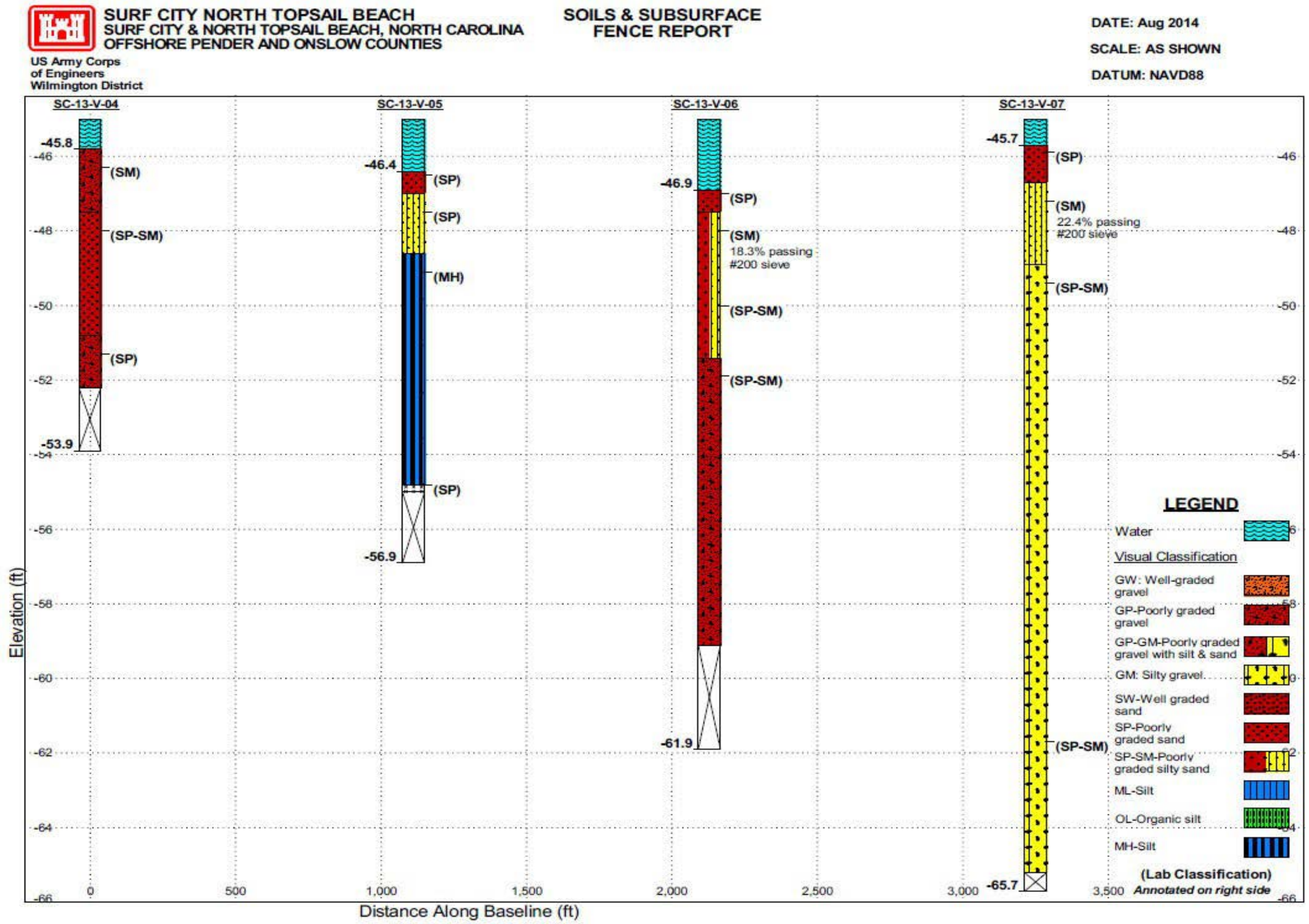


Figure 38. 2-D geologic cross section in Borrow Area N, profile N3. Bearing SW to NE.

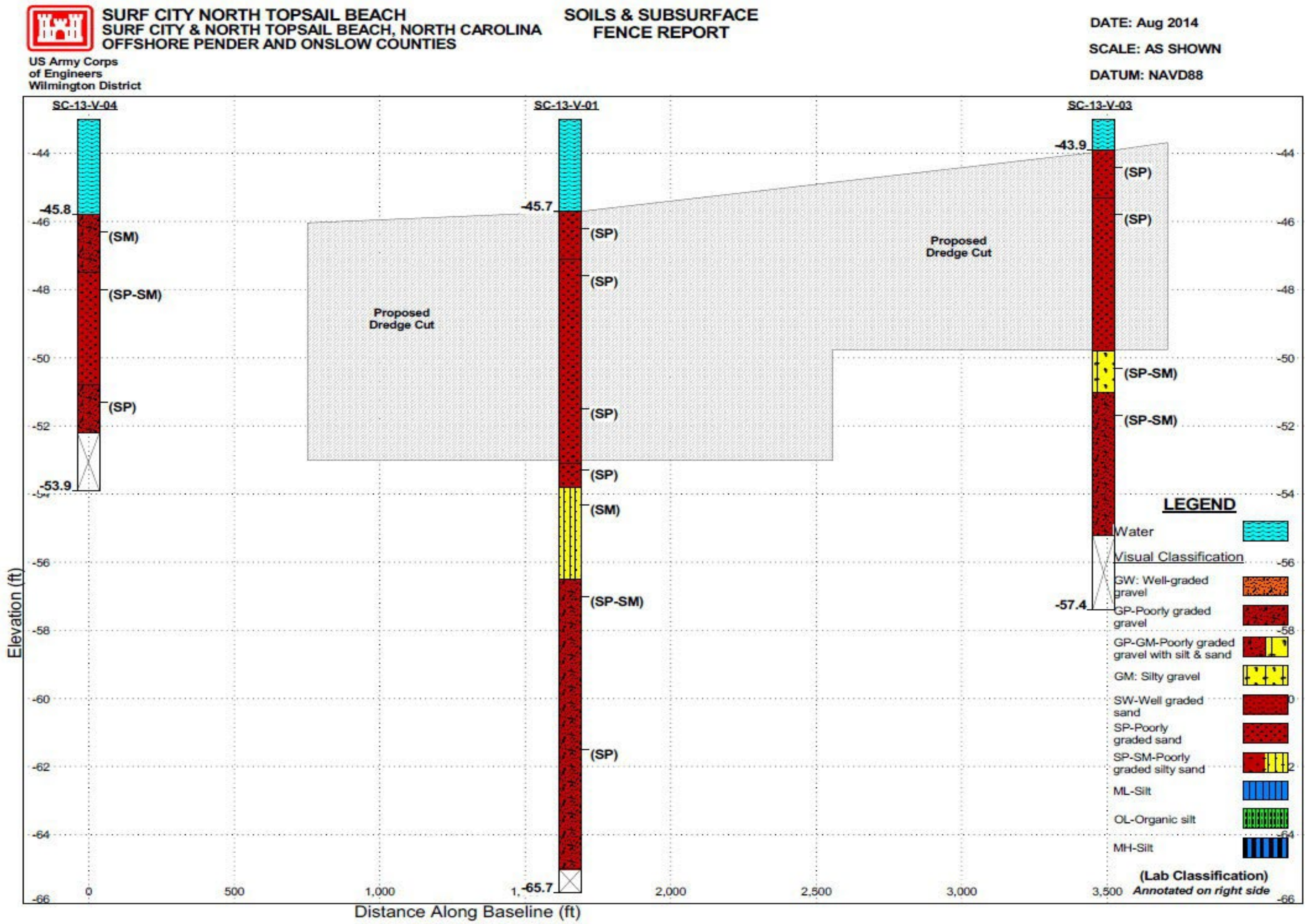


Figure 39. 2-D geologic cross section in Borrow Area N, profile N4. Bearing SW to NE.

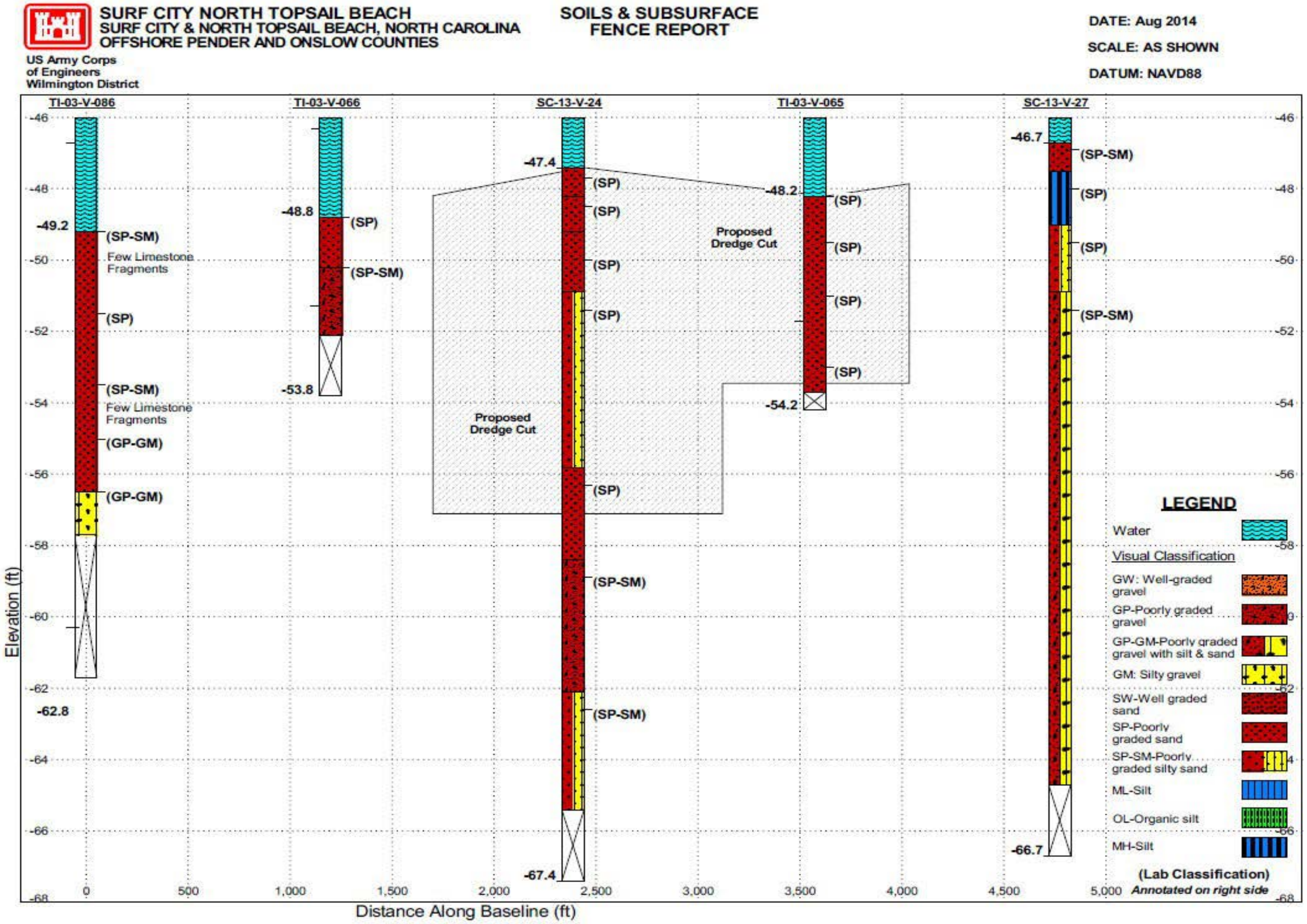


Figure 40. 2-D geologic cross section in Borrow Area N, profile N5. Bearing SW to NE.

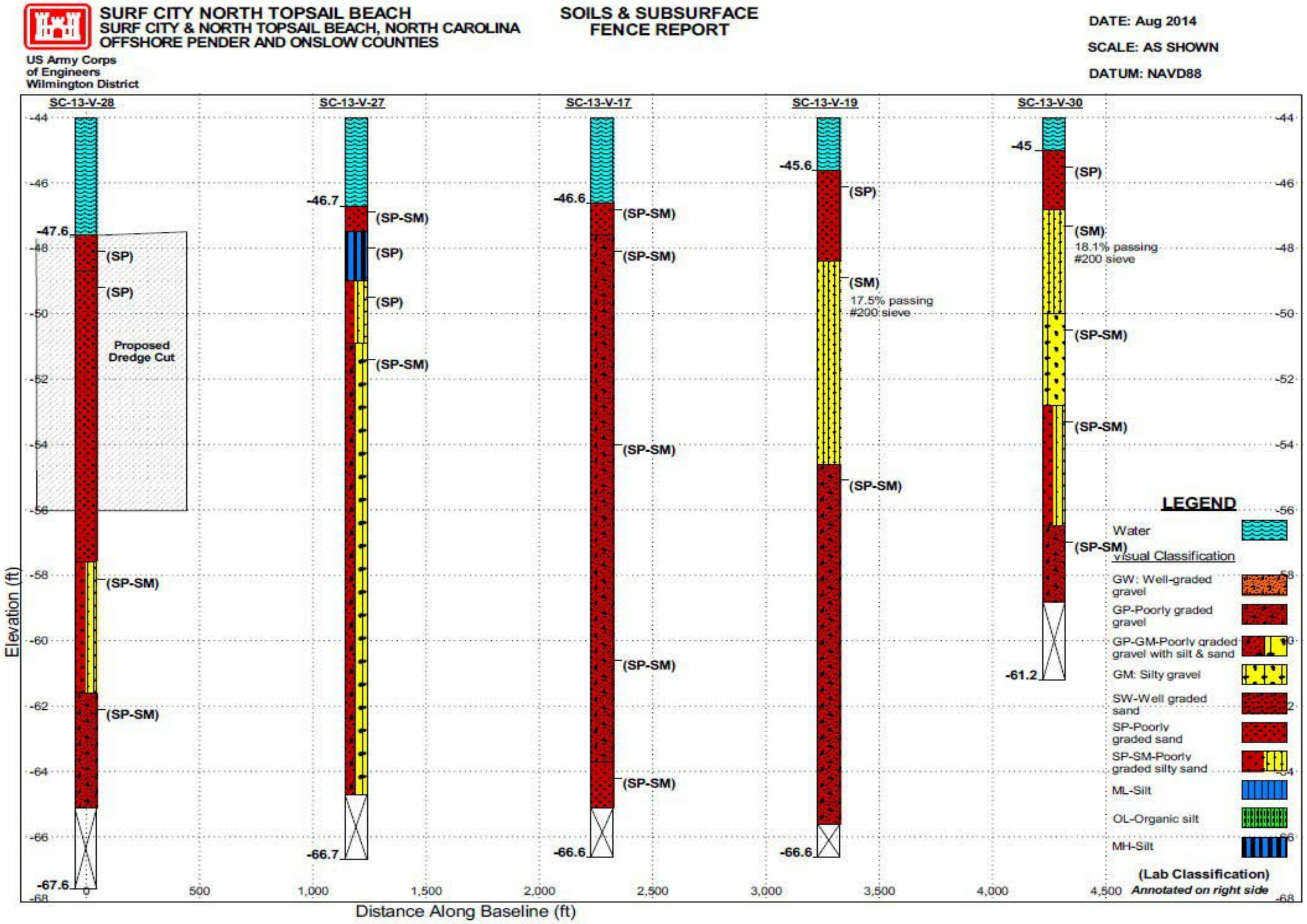


Figure 41. 2-D geologic cross section in Borrow Area N, profile N6. Bearing SE to NW.

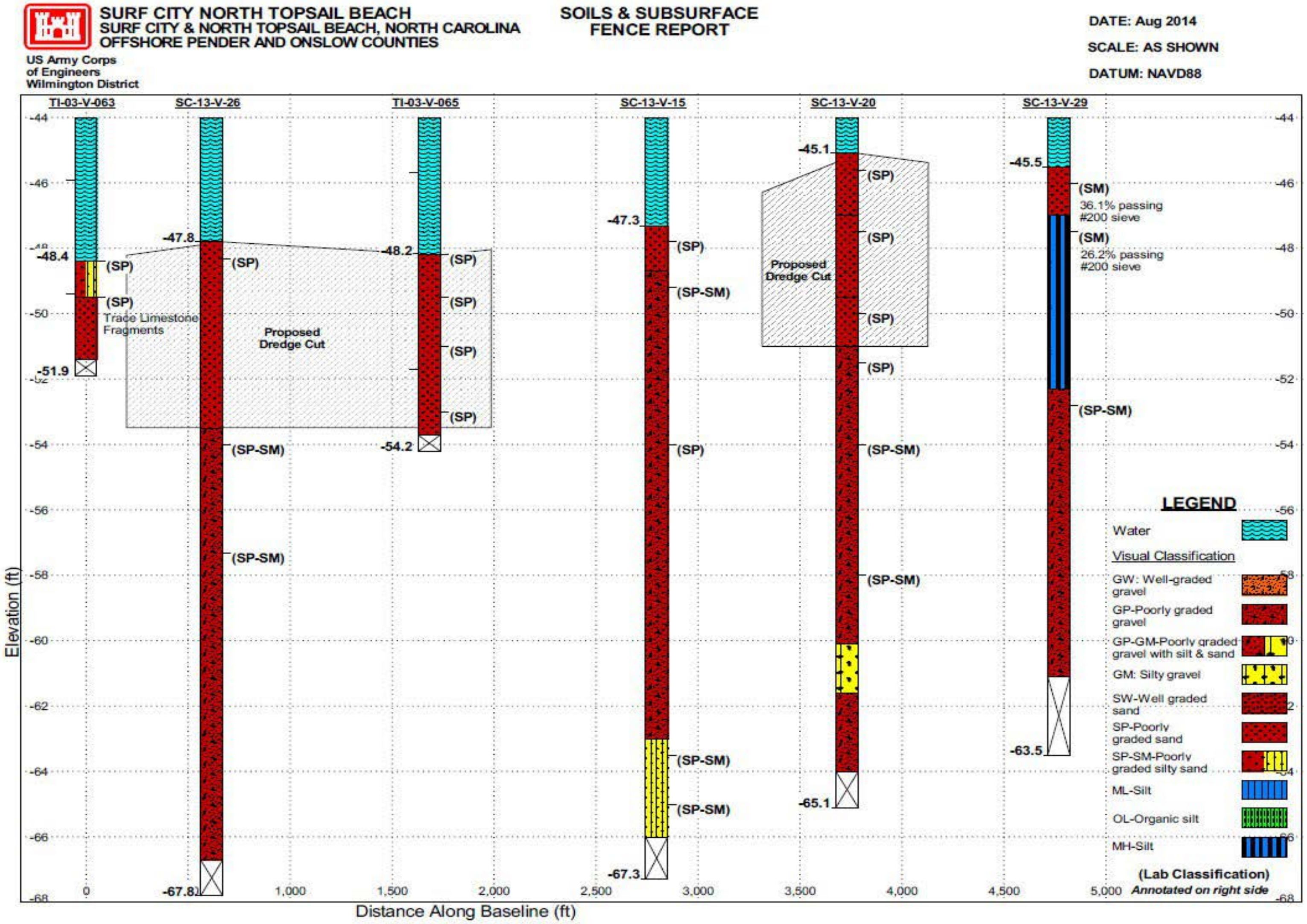


Figure 42. 2-D geologic cross section in Borrow Area N profile N7. Bearing SE to NW.

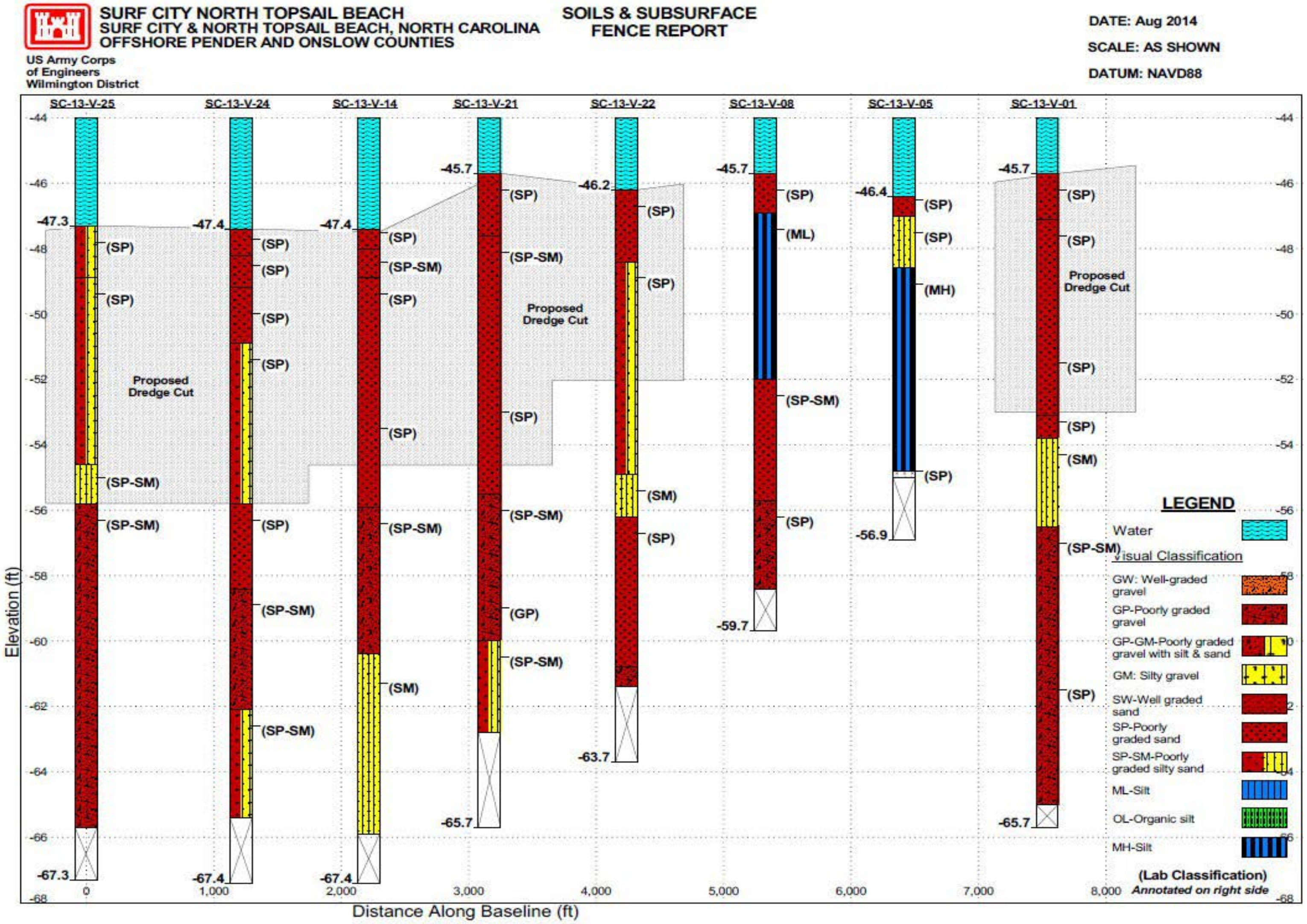


Figure 43. 2-D geologic cross section in Borrow Area N, profile N8. Bearing SE to NW.

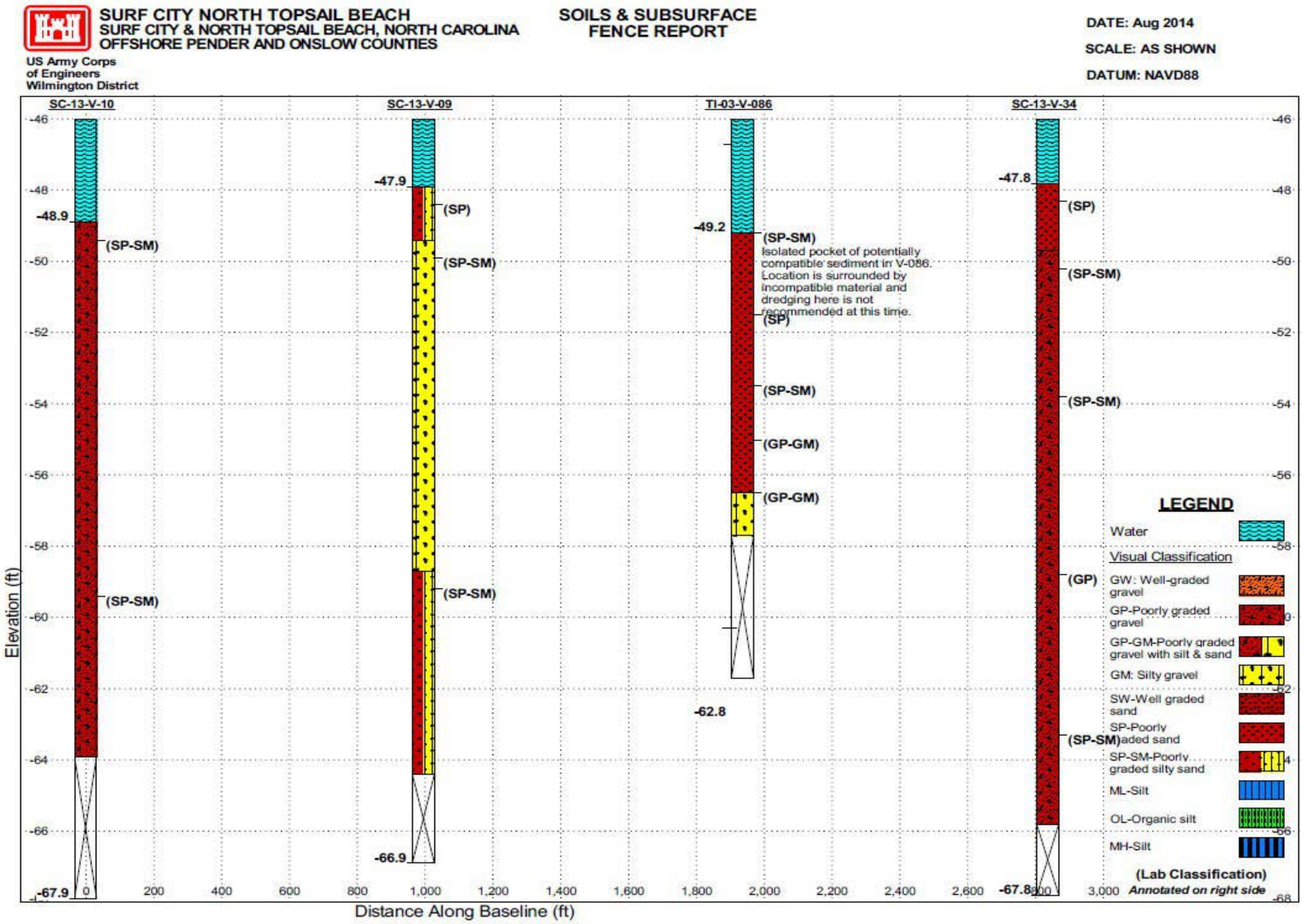


Figure 44. 2-D geologic cross section in Borrow Area N, profile N9. Bearing NW to SE.

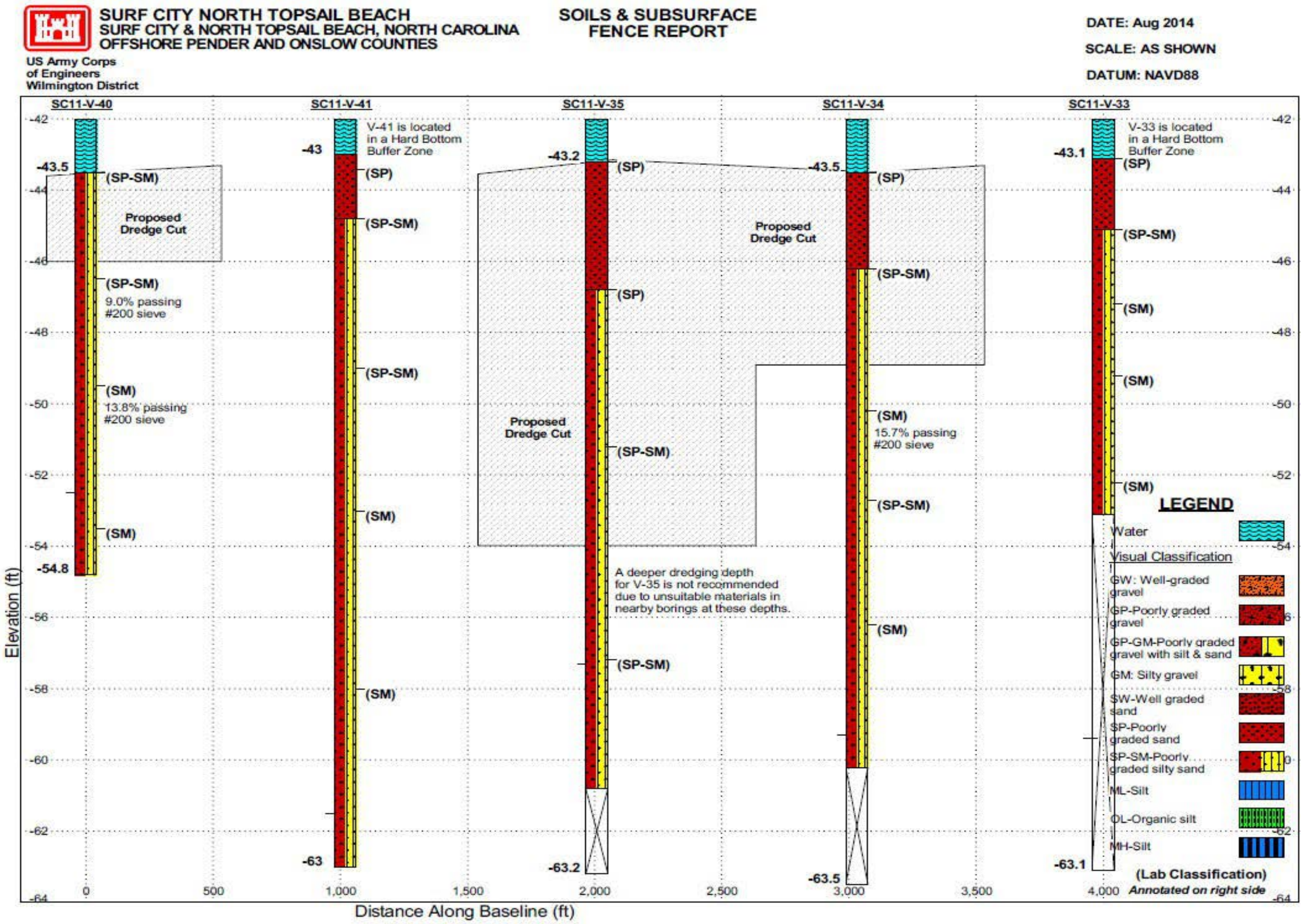


Figure 45. 2-D geologic cross section in Borrow Area O, profile O1. Bearing SW to NE.

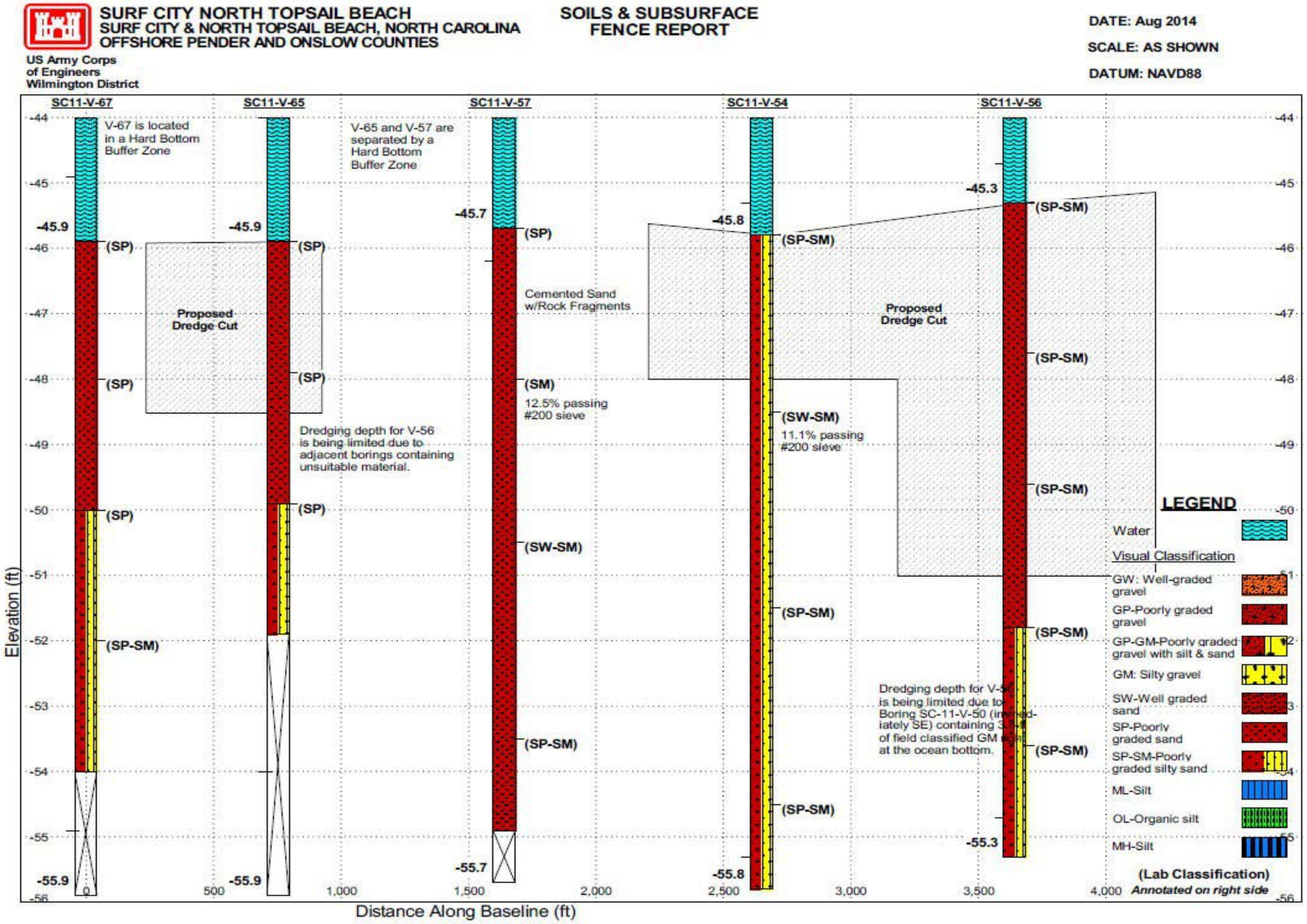


Figure 46. 2-D geologic cross section in Borrow Area O, profile O2. Bearing SW to NE.

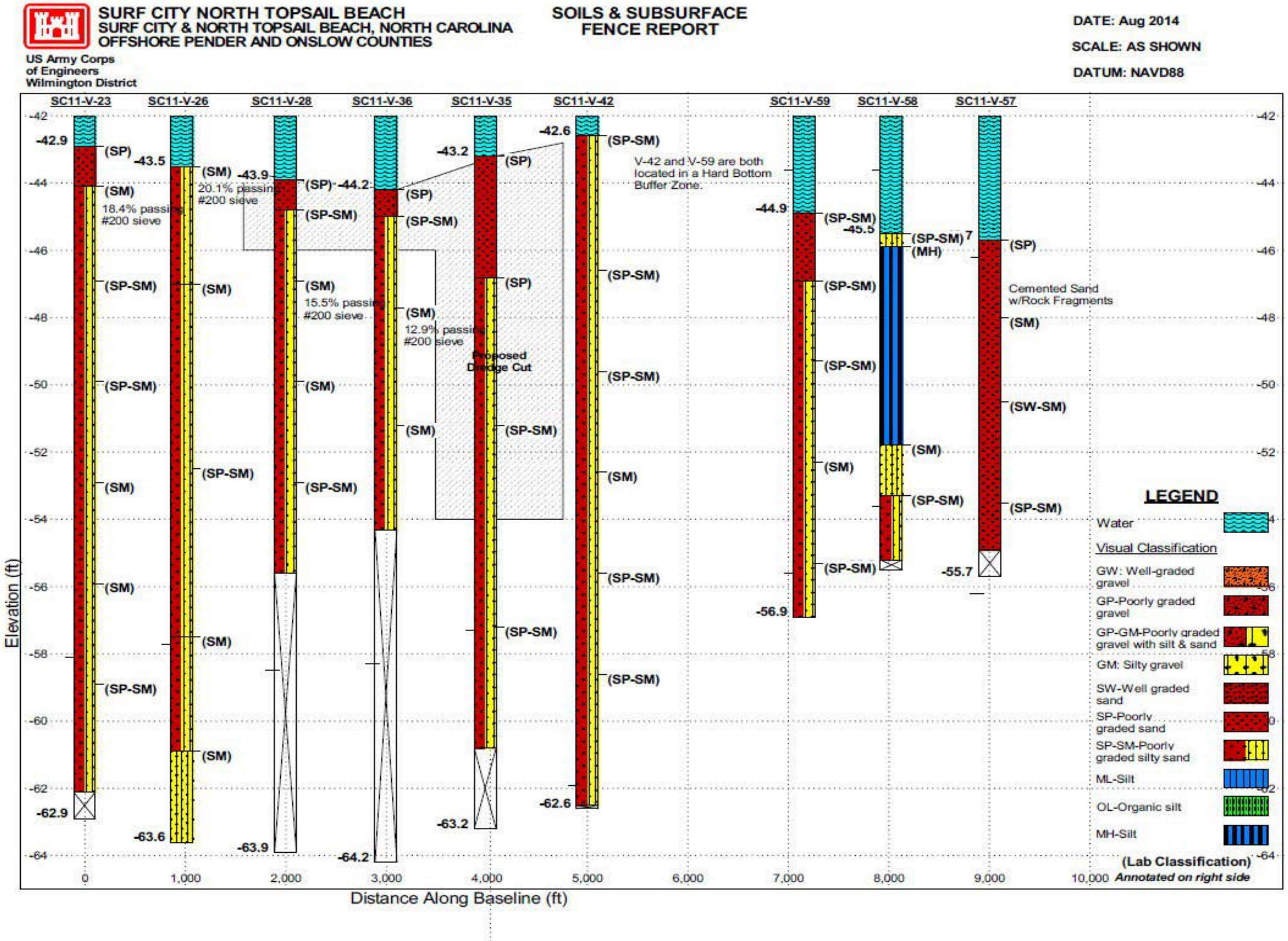


Figure 47. 2-D geologic cross section in Borrow Area O, profile O3. Bearing NW to SE.

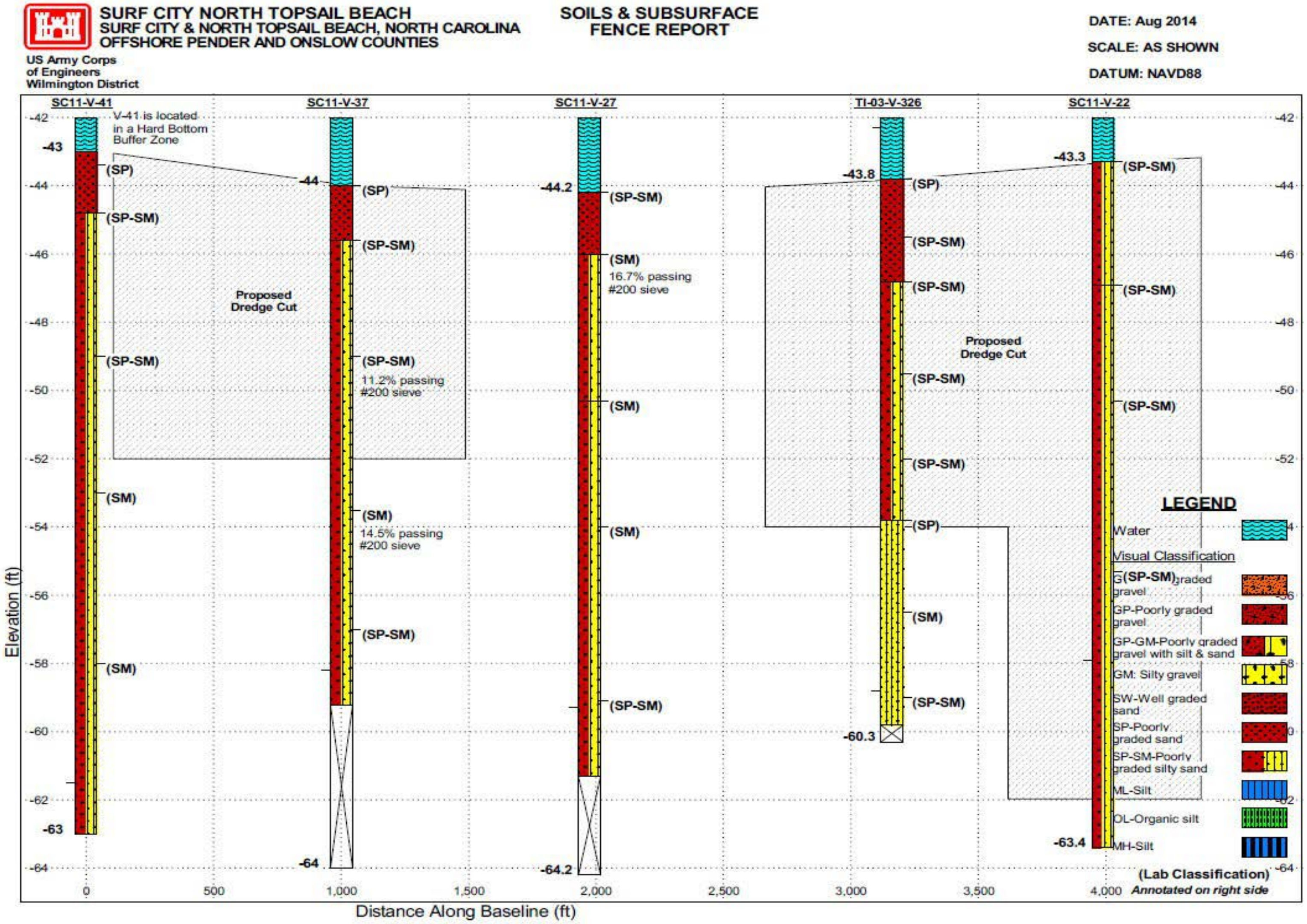


Figure 48. 2-D geologic cross section in Borrow Area O, profile O4. Bearing SE to NW.

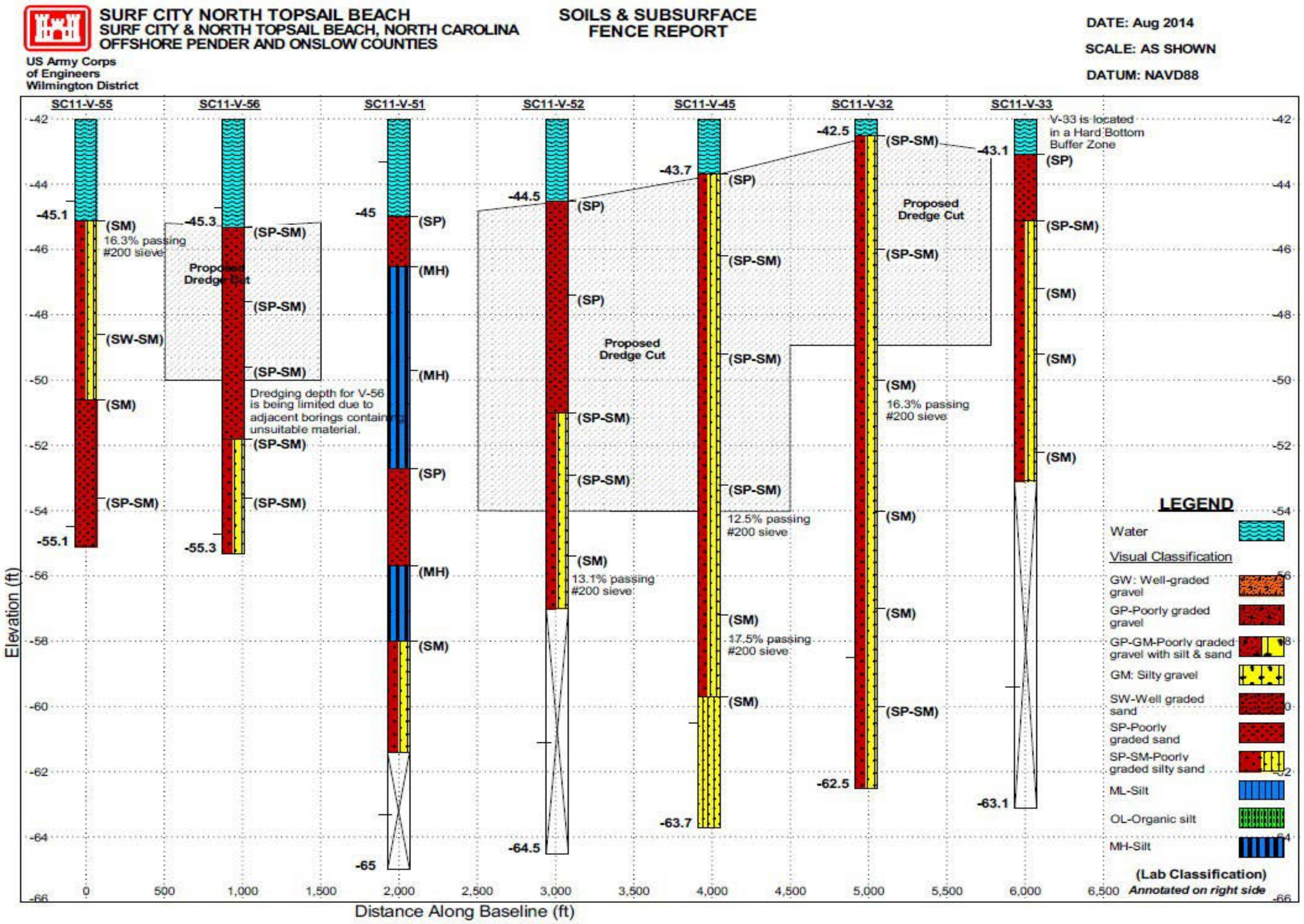


Figure 49. 2-D geologic cross section in Borrow Area O, profile O5. Bearing SE to NW.

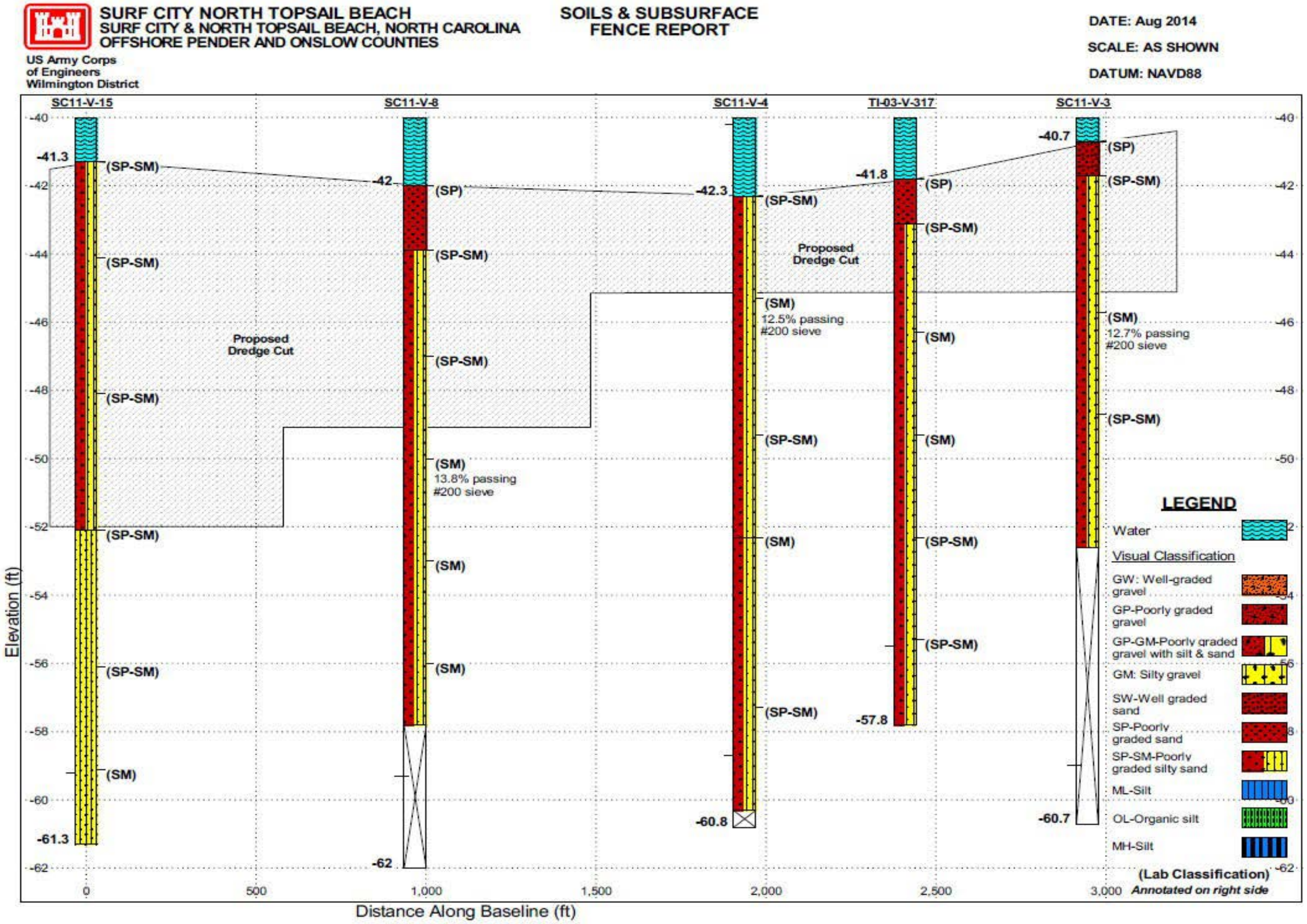


Figure 50. 2-D geologic cross section in Borrow Area P, profile P1. Bearing SE to NW.

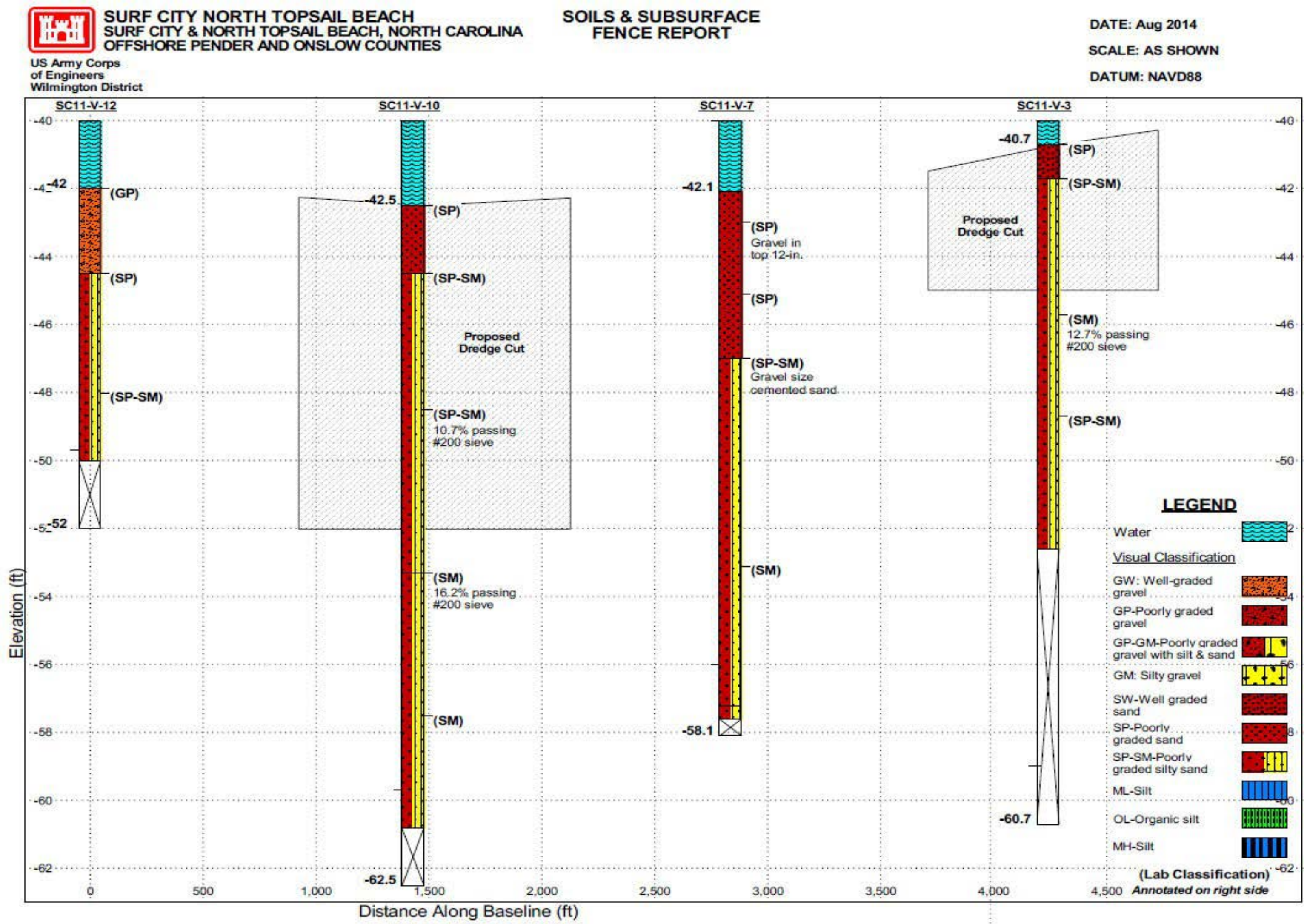


Figure 51. 2-D geologic cross section in Borrow Area P, profile P2. Bearing S to N.

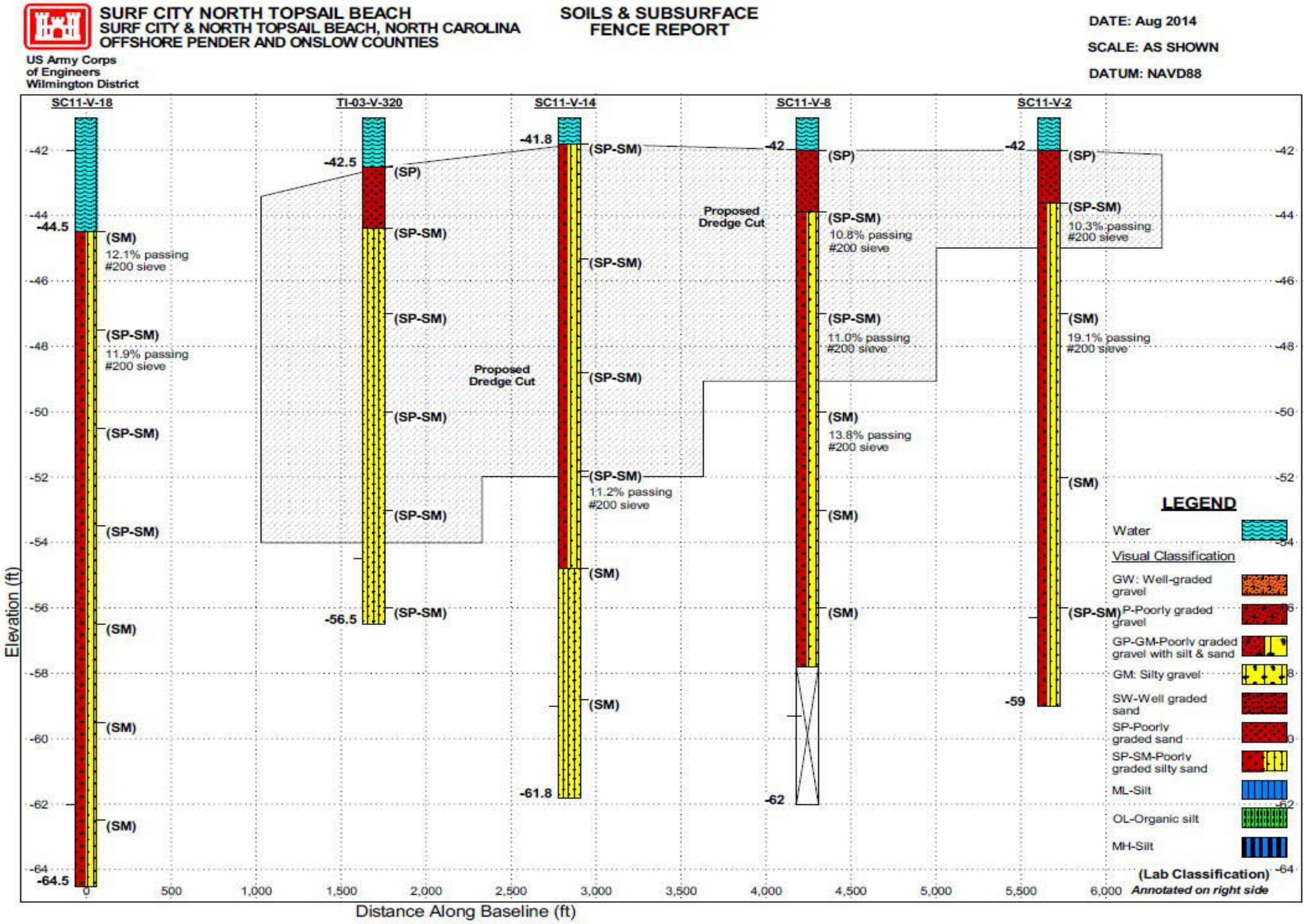


Figure 52. 2-D geologic cross section in Borrow Area P, profile P3. Bearing S to N.

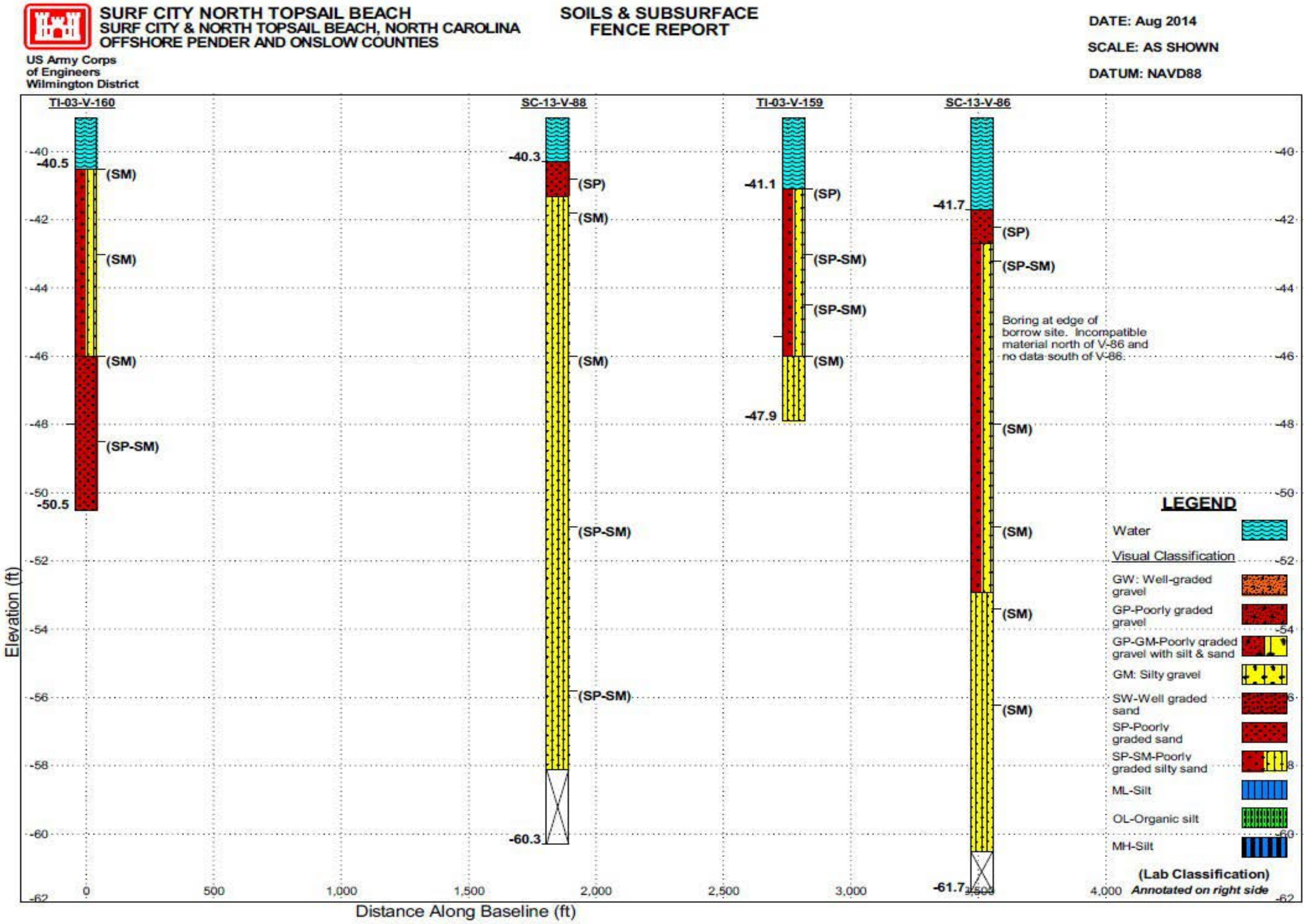


Figure 53. 2-D geologic cross section in Borrow Area R, profile R1. Bearing NW to SE.

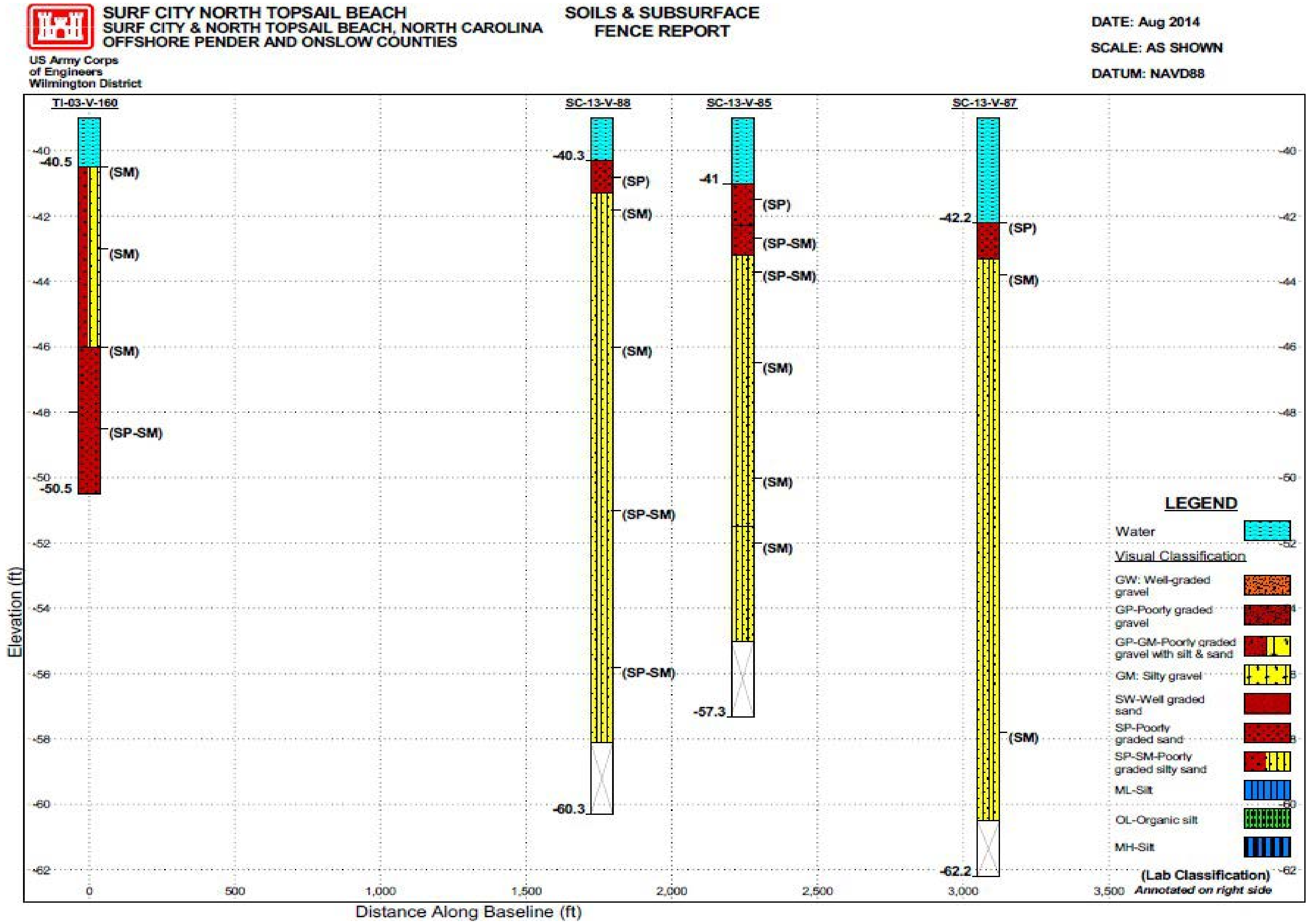


Figure 54. 2-D geologic cross section in Borrow Area R profile R2. Bearing N to SE.

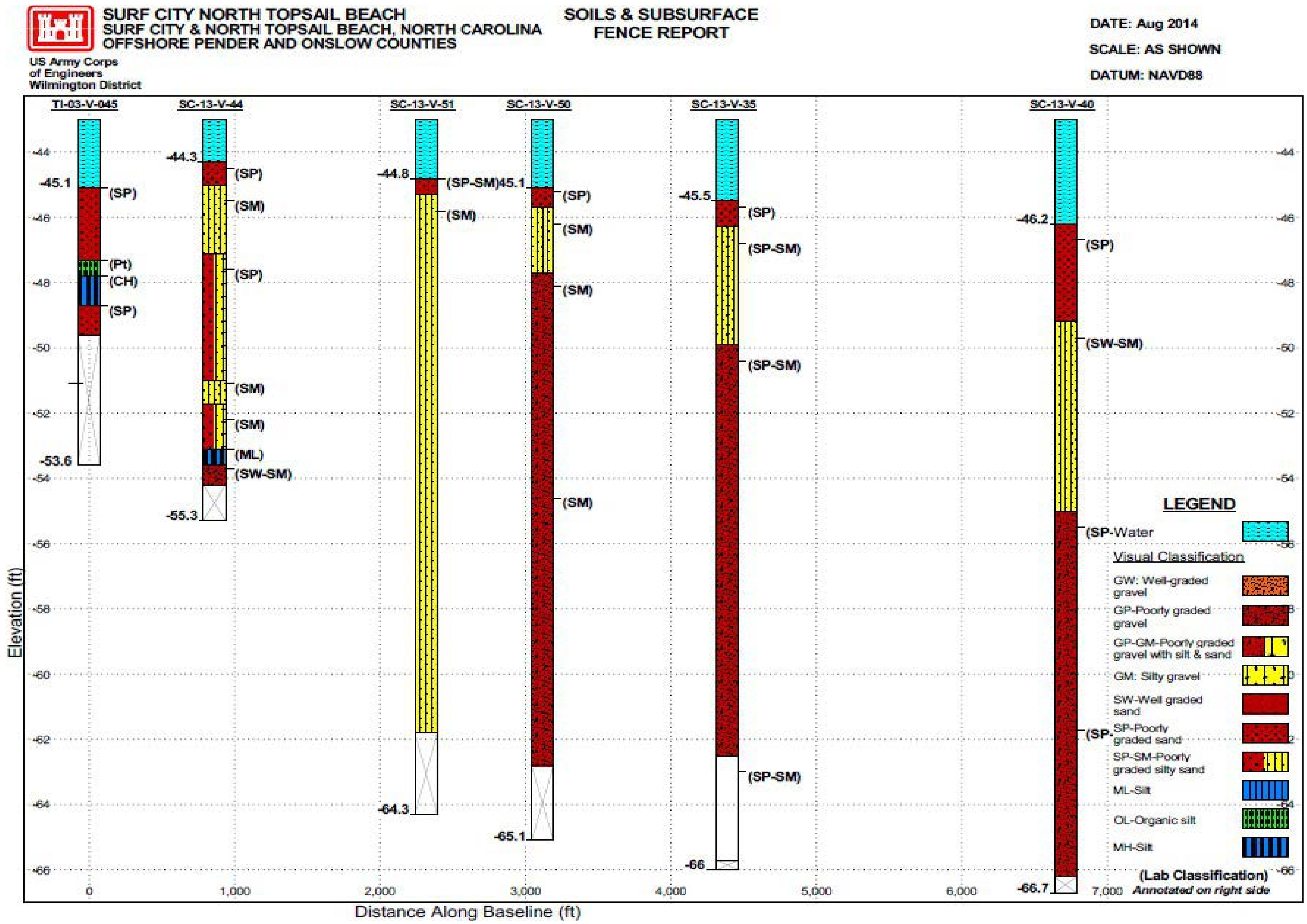


Figure 55. 2-D geologic cross section in Borrow Area S, profile S1. Bearing NW to SE.

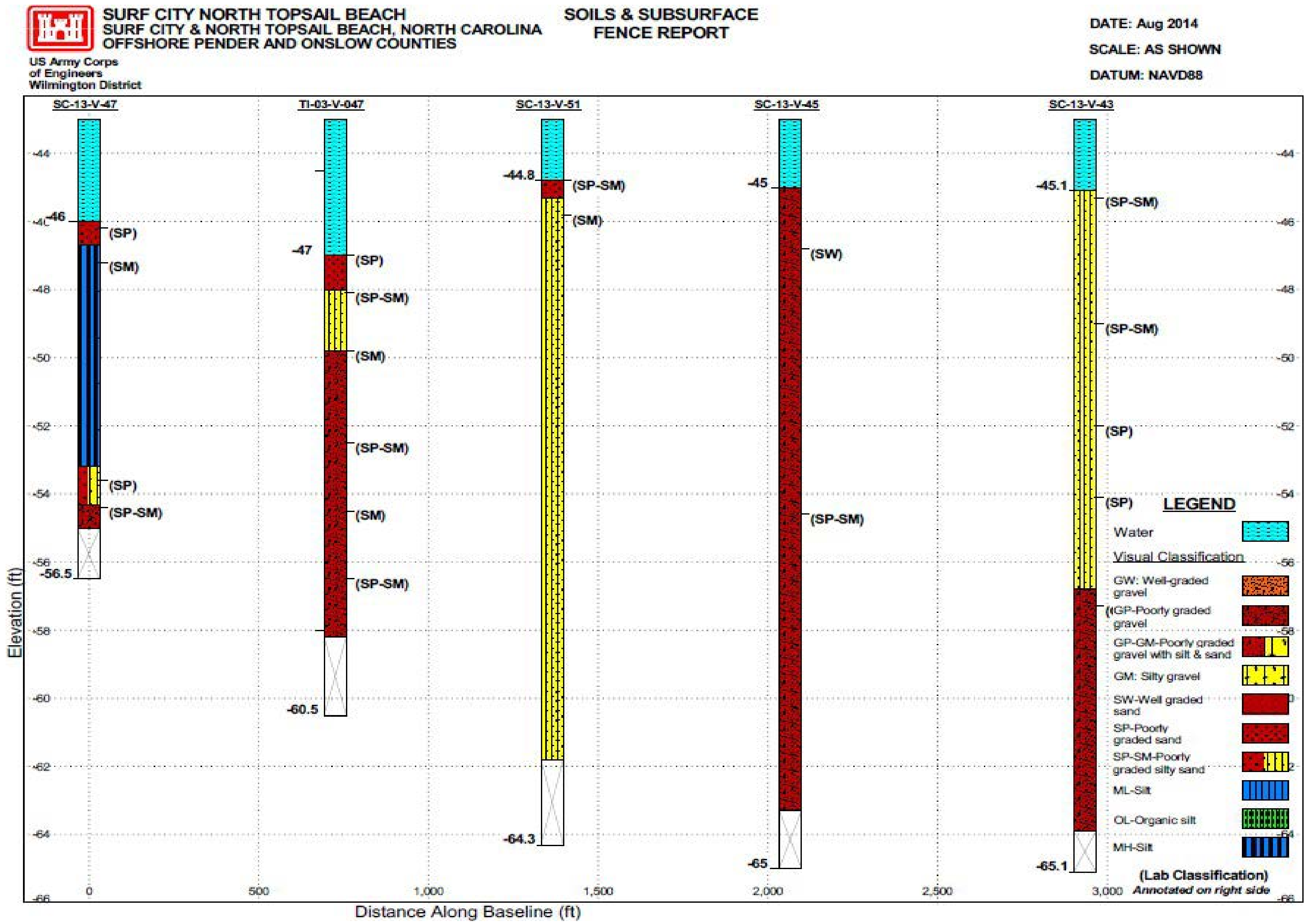


Figure 56. 2-D geologic cross section in Borrow Area S, profile S2. Bearing WSW to ENE.

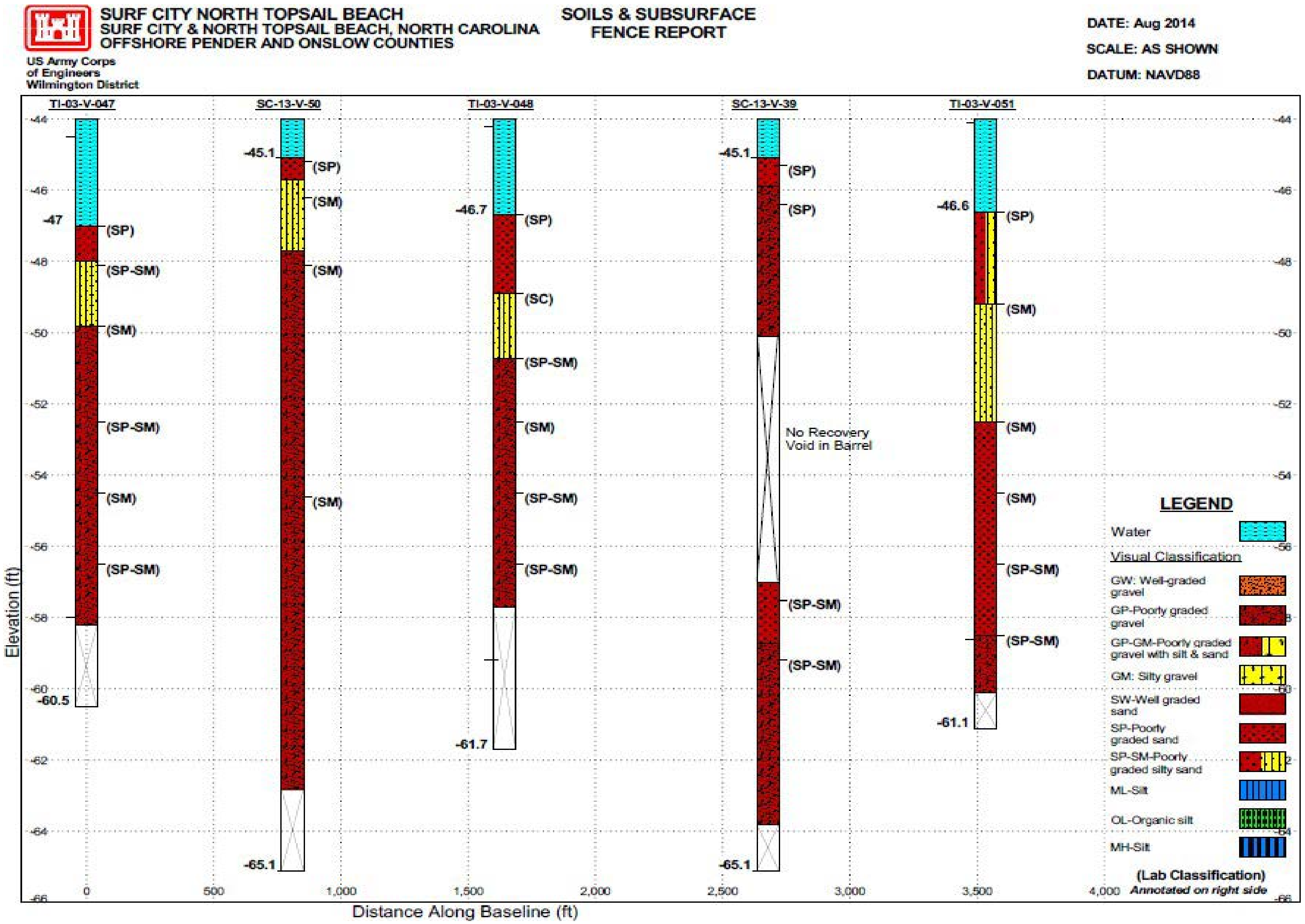


Figure 57. 2-D geologic cross section in Borrow Area S, profile S3. Bearing WSW to ENE.

Compatibility Analysis

Borrow Area Compatibility Data

A particle size analysis was performed for each sample documented on the 2003, 2011, and 2013 boring logs (Addendum A-1). The particle size characteristics of the samples were used to develop a weighted composite grain size distribution that is representative of the material in each borrow area. In order to determine the composite characteristics of each borrow area, each core is first weighted based upon the usable thickness of material in the core and then the sum weighted characteristics from the cores are divided by the total usable thickness. The Wilmington District practice with regard to the percentage of fine-grained sediments is that borrow areas containing more than 10 percent fines passing the #200 sieve are considered to be incompatible for placement on the beach due to potential problems with increased turbidity and siltation during placement. Included in the analysis was an estimate of the amount of fine-grained sediments in each core that is finer than the #230 sieve (0.0625 millimeters). For comparison, the standard set by the State of North Carolina in 2007 for governing sediment compatibility for beach nourishment is discussed in this report[2]. The state standard provides that "the average percentage by weight of fine-grained sediment (less than 0.0625 millimeters) in each borrow site shall not exceed the average percentage by weight of fine-grained sediment of the recipient beach characterization plus five (5) percent" (15A NCAC 07H.0312). The 15A NCAC 07H.0312 also states that "the average percentage by weight of calcium carbonate (shell) in a borrow site shall not exceed the average percentage by weight of calcium carbonate of the recipient beach characterization plus 15 percent".

In addition, the weighted granular sediment within the borrow areas was evaluated using the #10 and #4 sieves, 2 millimeter and 4.76 millimeter, respectively. The Wilmington District prefers to restrict the amount of granular sediment placed onto beaches and bases their decisions the composite grain size distribution given under 15A NCAC 07H.0312, "the average percentage by weight of granular sediment in a borrow site shall not exceed the average percentage by weight of coarse-sand sediment of the recipient beach characterization plus five (5) percent."

Table 3 lists the composite mean, standard deviation, weighted percent fines passing the #230 sieve, visual percent shell content, and weighted percent passing the #10 sieve for the native beach and each borrow area evaluated in 2011 and Borrow Area N, evaluated in 2013. Table 3 also compares the results for the USACE practice and state

[2] This project is a federal project and does not have to follow the nourishment standard set by the state of North Carolina. All the references to the state standard are for informational purposes.

standard for sediment finer than the #230 sieve in Borrow Areas G, H, J, L, N, O and P evaluated for composite percent fines content of 6.3 percent[3] and under 10 percent. The final weighted composite characteristics for each boring within Borrow Areas G, H, J, L, N, O and P are given in Appendix A-2 and are divided based on the state standard and USACE practice.

Table 3. Mean sampling data from the native beach on Topsail Island and borrow areas.

Data	Native Beach[4]	Borrow Area G		Borrow Area H		Borrow Area J		Borrow Area L		Borrow Area O		Borrow Area P		Borrow Area N	
		State	USACE	State	USACE	State	USACE	State	USACE	State	USACE	State	USACE	State	USACE
Mean (phi)	2.15	2.26	2.17	2.45	2.48	2.01	1.92	1.63	1.57	2.18	2.22	2.05	2.32	2.07	2.07
Std Dev (phi)	0.7	0.7	0.9	0.5	0.5	0.9	0.9	1.3	1.4	0.8	0.7	0.9	0.7	0.7	0.7
Weight % Fines (passing #230)	1.3	4.5	5.1	3.1	3.2	3.5	3.8	3.8	4.8	5.5	6.4	6.1	8.3		2.5
Weight % Fines (passing #200)		4.2	5.4	3.0	3.4	2.8	4.0	2.8	5.0	4.7	6.7	5.1	8.6		2.4
Visual % Shell	9.4	3.8	3.4	2.8	2.2	8.7	7.9	12.3	11.8	5.3	3.4	4.2	3.0	12.7	12.7
Weight % Passing #10	98.1	96.2	94.8	98.6	98.8	94.6	92.7	90.0	87.9	94.8	95.1	93.8	96.5	94.8	94.8

Based on Table 3 the suitable material in Borrow Areas G and H contains less than 6.3 percent fines and contains minimal shell and granular sediment. The shell content for Borrow Area J is slightly higher than the content of Borrow Areas G and H but is still considered acceptable. Granular sediment for Borrow Area J is slightly below the state standard (93.1 percent). Borrow Area L contains suitable material based on fines and shell content, but the borrow area contains a bit more granular material than allowed in 15A NCAC 07H.0312. The additional amount of granular material is not expected to greatly affect the quality of the material. In addition, it is expected that the granular material quantities may be reduced through the dredging process for placing the material on the beach. Both Borrow Areas O and P are suitable for shell and granular material, but the USACE evaluation contains slightly more fines than 6.3 percent. Borrow Area N was evaluated based upon USACE criteria but not upon State criteria. Relative to the actual size of Borrow Area N, the volume of available suitable and dredgable sediments is comparatively small. Due to the limited volume and the USACE evaluation taking precedence in construction of a Federal project, evaluation of sediments according to State criteria was not completed. Overall, the material from

[3]This value is 5 percent plus the native beach 1.3 percent fines.
[4] Refer to Section 4 Methodology, Native Beach Sampling.

Borrow Areas G, H, J, L, N, O and P are compatible to the native beach of Surf City and North Topsail.

Overfill Ratios

While borrow area mineralogy and grain size statistics are important considerations when determining material compatibility, overfill ratios provide essential information when considering material volumes for beach nourishment construction. The overfill ratio is computed by numerically comparing the size distribution characteristics of the native beach sand with that of the borrow site, including an adjustment for the percentage of fines within the borrow site. The overfill ratio is based on the assumption that borrow material will undergo winnowing once exposed to waves and currents in the littoral zone, with the resulting sorted distribution approaching that of the native sand. Since borrow material will rarely match the native material exactly, the amount of borrow material needed to result in one net cubic yard of beach fill material will generally be greater than one cubic yard. Additionally, overfill ratios increase with increasing fines content within a given borrow area. Thus, the overfill ratio represents the borrow volume needed to fill a given beach template compared to the net sand needed for that same template. For example, if 1.5 cubic yards of stable fill material is needed to yield 1.0 cubic yard (net) on the beach, the overfill factor would equal 1.5.

USACE's Technical Memorandum No. 60, Techniques for Evaluating Suitability of Borrow Material for Beach Nourishment (James, 1975), reviews various methods for determining overfill ratios, such as the Dean and the Adjusted Fill Factor (AFF) methods. Thus, overfill ratios were assessed using these techniques and were then compared with outputs produced by USACE's Coastal Engineering Design and Analysis System (CEDAS) software. All three methods compare standard deviation ratios to mean ratio values of both the native beach and borrow area sands. The coarseness of Surf City/North Topsail Beach borrow area material compared to native beach sand produced a broad range of overfill ratios prior to the calculation of fine-grain content adjustments. The Dean method was useful for qualitative analysis and revealed that material from all proposed dredge boxes should remain at least be equal to the grain size of the native beach sand. However, determining a quantitative ratio via Dean was not practical, as this approach does not allow for interpolation of overfill values when borrow area material is coarser than native beach sand. The AFF method is more conservative than Dean, but also produced results indicating that borrow area grain sizes were either equal to or greater than native beach grain size. Ultimately, the most conservative overfill ratio values from AFF and CEDAS calculations were selected from each borrow area, followed by respective fines content adjustments to produce the values shown in Table 4 below.

Table 4. Comparison of borrow area overfill ratios.

	Borrow Area	Silt Correction Factor[5]	AFF Overfill Ratio	AFF Final[6]	Dean	Dean Final[5]	CEDAS	CEDAS Final
UNDER 6.3% SILTS	B	1.05	1.10	1.16	1.02	1.07	1.16	1.22
	C	1.05	1.70	1.78	1.20	1.26	1.53	1.60
	D	1.06	1.15	1.22	1.00	1.06	1.14	1.21
	E	1.04	1.10	1.14	1.00	1.04	1.03	1.07
	F	1.05	1.05	1.10	1.00	1.05	1.02	1.07
	G	1.05	1.10	1.15	1.10	1.15	1.22	1.28
	H	1.03	3.50	3.61	2.00	2.06	4.61	4.76
	J	1.03	1.05	1.08	1.00	1.03	1.04	1.07
	L	1.04	1.10	1.14	1.00	1.04	1.10	1.14
	O	1.06	1.05	1.11	1.05	1.11	1.06	1.12
	P	1.07	1.02	1.09	1.00	1.07	1.01	1.08
UNDER 10% SILTS	**Borrow Area**	**Silt Correction Factor[4]**	**AFF Overfill Ratio**	**AFF Final[5]**	**Dean**	**Dean Final[5]**	**CEDAS**	**CEDAS Final[5]**
	A	1.08	1.25	1.35	1.15	1.24	1.45	1.57
	G	1.06	1.15	1.22	1.02	1.08	1.18	1.25
	H[7]	1.03	10.00	10.35	2.00	2.07	65.69	67.99
	J	1.04	1.10	1.15	1.00	1.04	1.02	1.06
	L	1.05	1.13	1.19	1.00	1.05	1.11	1.17
	O	1.07	1.10	1.18	1.10	1.18	1.03	1.10
	P	1.09	1.50	1.64	1.25	1.37	1.13	1.24
	N	1.03	1.03	1.06	1.00	1.03	1.37	1.40

6 Summary and Results

The PED portion of the Surf City and North Topsail Beach CSDR project, inclusive of Phase I (2011) and Phase II (2013), included the evaluation of Borrow Areas E, F, G, H, J, L, N, O, P, R, and S. The evaluation included vibracore sampling of the borrow areas and compatibility analysis of the sampled materials. Based on the geology, it was known prior to PED that the seafloor within the vicinity of the borrow areas consisted primarily of weathered Oligocene silty sandstone, outcroppings of Oligocene limestone hard bottoms, and paleofluvial channels. Geophysical surveys and in-situ diver ground truthing were used for further evaluation and showed that hard bottom was present within seven of the eleven evaluated borrow areas. Based on the comprehensive evaluation of the nearshore data collected through side-scan and multi-beam surveys, diver ground truth surveys, and additional historic offshore side-scan data, it was concluded that previously documented “potential hard bottom” targets are consistent

[5] Silt factor was computed by: (1/(1-(Percent of Fines/100)))

[6] All final overfill ratio values were multiplied by the silt correction factor.

[7] These ratios are unexpectedly high, given the similarity of grain characteristics within this borrow area compared to others. Thus, these overfill ratios are likely influenced by large standard deviations, which could be mitigated by future fieldwork which would increase the number of samples (n) and narrow the standard deviations ranges.

with descriptions RSD, RCD, and sorted bedform features (See Figures 4 and 5). During the vibracore sampling, those areas known to be characterized as hard bottom, cemented and/or indurated, RSD, RCD, or sorted bedforms were avoided.

The laboratory results from each of the vibracores from Borrow Areas G, H, J, L, N, O, and P were evaluated for their compatibility to the native beach material. The evaluation involved determining the percent granular and fine grain material in each sample as well as the percentage of calcium carbonate. The results show that there is usable beach fill material in each of the aforementioned borrow areas. Borrow Area P contains the greatest quantity of fines at 8.3 percent while Borrow Area L contains the greatest amount of granular material at 87.9 percent passing the #10 sieve. The composite calcium carbonate percentage is highly variable but within allowable limits for beach fill.

The Dean, AFF, and CEDAS methods were used to calculate overfill ratios for each composited borrow area. All three models show that losses will be minimal for borrow areas G, L, J, O, and P with those values increasing with increased fines content. Borrow Area H showed unexpectedly high overfill ratios which can be attributed to large standard deviations and/or the borrow material being coarser than the native beach. Inevitably there will be losses due to the mechanics of transporting the material and wave action on the beach. Additionally, extremely high overfill ratios are unrealistic and represent the limitations of each respective model.

Initial Construction and Beach Fill Placement

Initial construction volumes were determined from post Hurricane Irene monitoring surveys taken in September and October 2011. Given the amount of time that has passed and subsequent storm impacts, an updated survey is being performed to verify initial construction volume needs. Survey results, including bathymetry and track lines, will be updated within this Geotechnical Appendix when received. Considering all of the offshore resources for Topsail Island, 8 borrow areas (A, G, H, J, L, N, O, and P) were found to contain approximately 35.8 million cubic yards of beach suitable sand which would cover the originally estimated 50-year project need of approximately 32.3 million cubic yards.

Table 5 lists PED and Feasibility volumes of beach-fill quality sand which can be expected from the borrow areas listed and is inclusive of all borrow areas that may potentially be utilized for initial construction or renourishment of the project. Borrow Areas A, B, C, and D, immediately southwest of Borrow Area E, were originally allocated for construction and renourishment of the West Onslow Beach CSDR project, a portion of which was intended to be supplemental to the Surf City and North Topsail Beach CSDR project. The West Onslow Beach CSDR Project reached PED Phase I in 2010, at which time Borrow Area A was evaluated for design level volumes. However, since that time the local authority has worked to procure the sand needed for beach nourishment from New Topsail Inlet allowing for utilization of these borrow areas as part of the Surf City & North Topsail Beach CSDR Project. A detailed analysis of Borrow Area A compatibility and volumes is included in the West Onslow Beach CSDR Geotechnical Appendix which is available upon request (Addendum A-1). Borrow Areas B, C, and D have only undergone a feasibility level investigation, and determining more accurate volumes would be required by means of 1,000 foot grid spacing subsurface investigation and compatibility analysis. Figure 61 is included here for reference and denotes dredge boxes and estimated available volumes for Borrow Area A.

Additionally, Borrow Area Q was identified as a potential source of suitable material and investigated during the Feasibility Phase. Using these limited data, USACE estimated a source volume of 730,000 cubic yards with a Mean (phi) of 2.30 (0.20 millimeters) and hard bottom present in several locations. Borrow Area Q was further investigated by North Topsail Beach via Coastal Planning and Engineering (CPE) which expanded the footprint of Borrow Area Q and provided geophysical surveys, subsurface data, and sediment characteristics (Finkl et al., 2007). In 2015, the project sponsor utilized the expanded Borrow Area Q for sand nourishment and, although the borrow area was estimated by CPE (2013) to contain 6,194,454 cubic yards of beachfill material, only 1,300,000 cubic yards were placed on the beach. The project sponsor reported issues with encountering rock and suggested further subsurface investigation would be needed to identify additional available volumes. Large discrepancies between volumes for this borrow area, reported in Table 5, are due to the expanded footprint, limited subsurface data, or the presence of cemented and/or indurated sands which are disturbed and physically altered during collection and analysis.

Compatibility analysis was not completed for Borrow Sites E, F, R, and S due to their difficulty of use which results from shallow water depth, difficulty of dredging, and apparently limited sand occurrence as isolated pockets. However, USACE or the project sponsor might consider utilizing these borrow sites as dredging technology improves. It is also important to note that the existing compatibility analysis for Borrow Area Q, which was performed by the private sector, is based on the State of North Carolina criteria and not that of USACE (See Compatibility Analysis for a description of each standard). Borrow Areas G, H, J, L, N, O, and P were found to be within USACE standards for compatibility and have been delineated with dredge boxes as shown in Figures 58-60. Estimated Borrow Area volumes reported include a total borrow area volume in cubic yards, and the respective material volumes within and beyond the territorial seas limit or 3 nautical mile line as shown in Figures 58-60 and listed in Table 5. Future work should focus on refining Borrow Areas B, C, D, and Q, and investigating other potential offshore sources which could be exploited for on-going support of recurring beach nourishment projects.

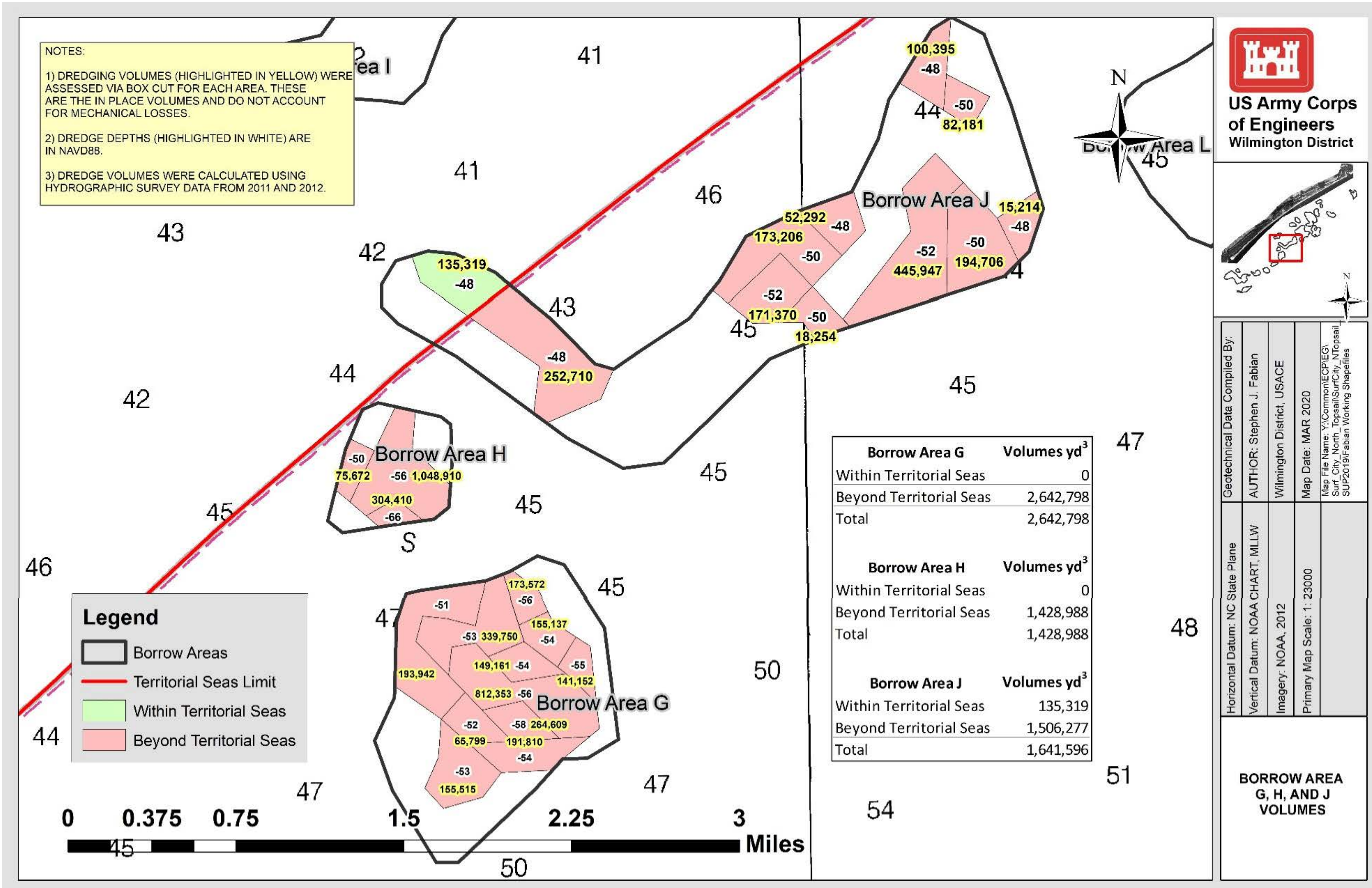


Figure 58. Borrow Areas G, H, and J dredge cut boxes and available volumes within and beyond the territorial sea limit (3 nautical mile line).

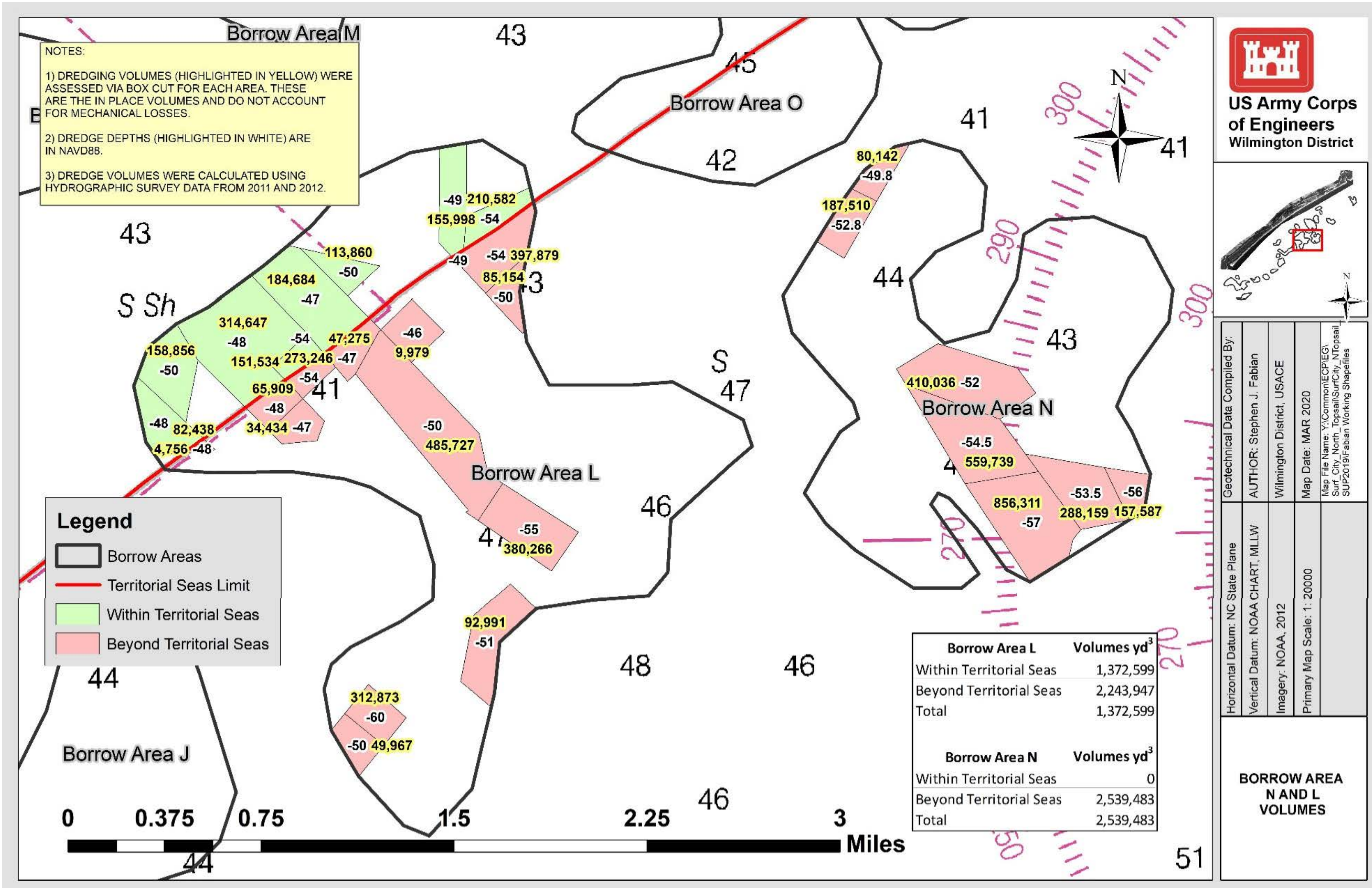
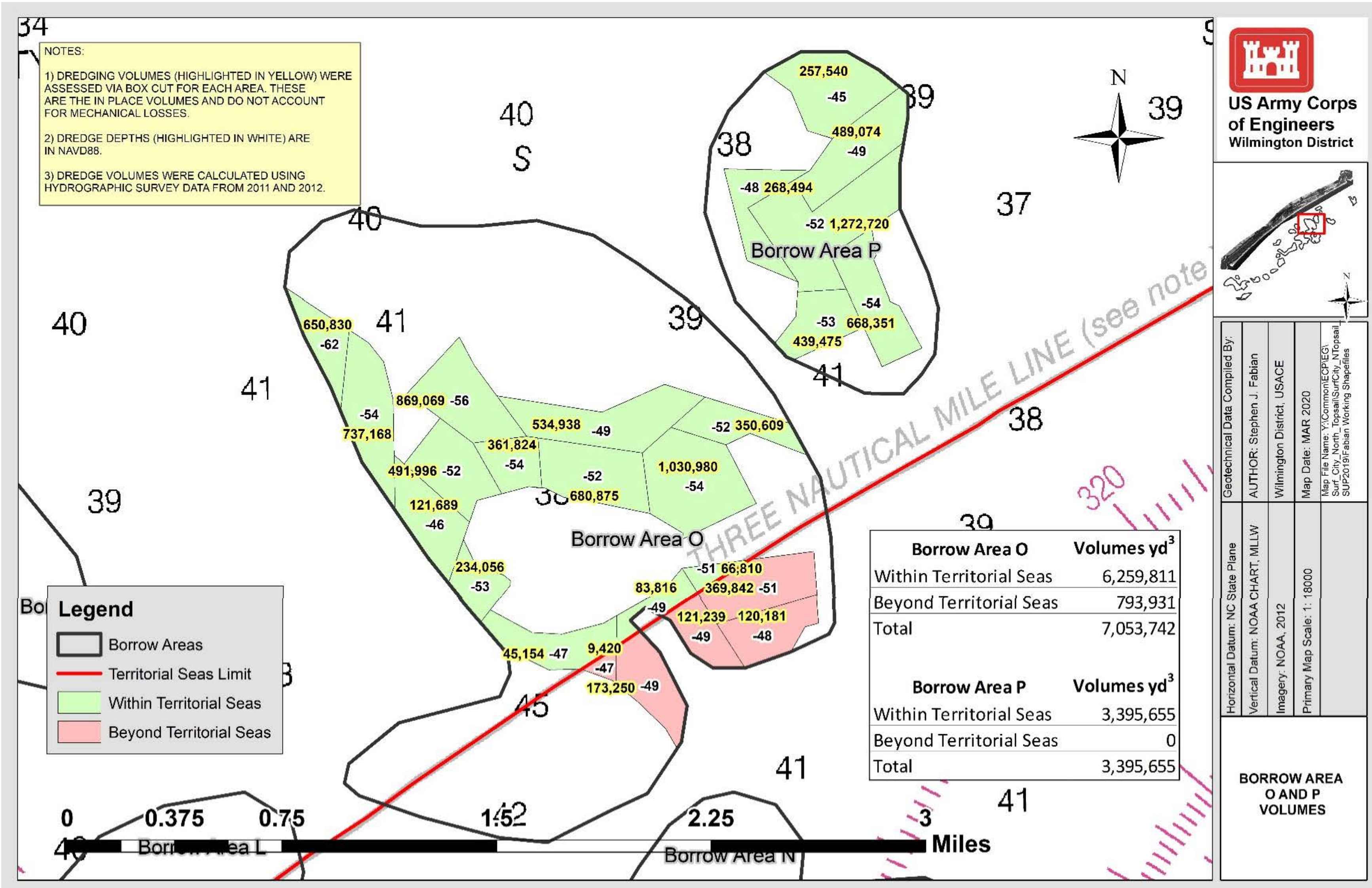


Figure 59. Borrow Areas L and N dredge cut boxes and available volumes within and beyond the territorial sea limit (3 nautical mile line).



Borrow Area O	Volumes yd^3
Within Territorial Seas	6,259,811
Beyond Territorial Seas	793,931
Total	7,053,742

Borrow Area P	Volumes yd^3
Within Territorial Seas	3,395,655
Beyond Territorial Seas	0
Total	3,395,655

Figure 60. Borrow Areas O and P dredge cut boxes and available volumes within and beyond the territorial sea limit (3 nautical mile line).

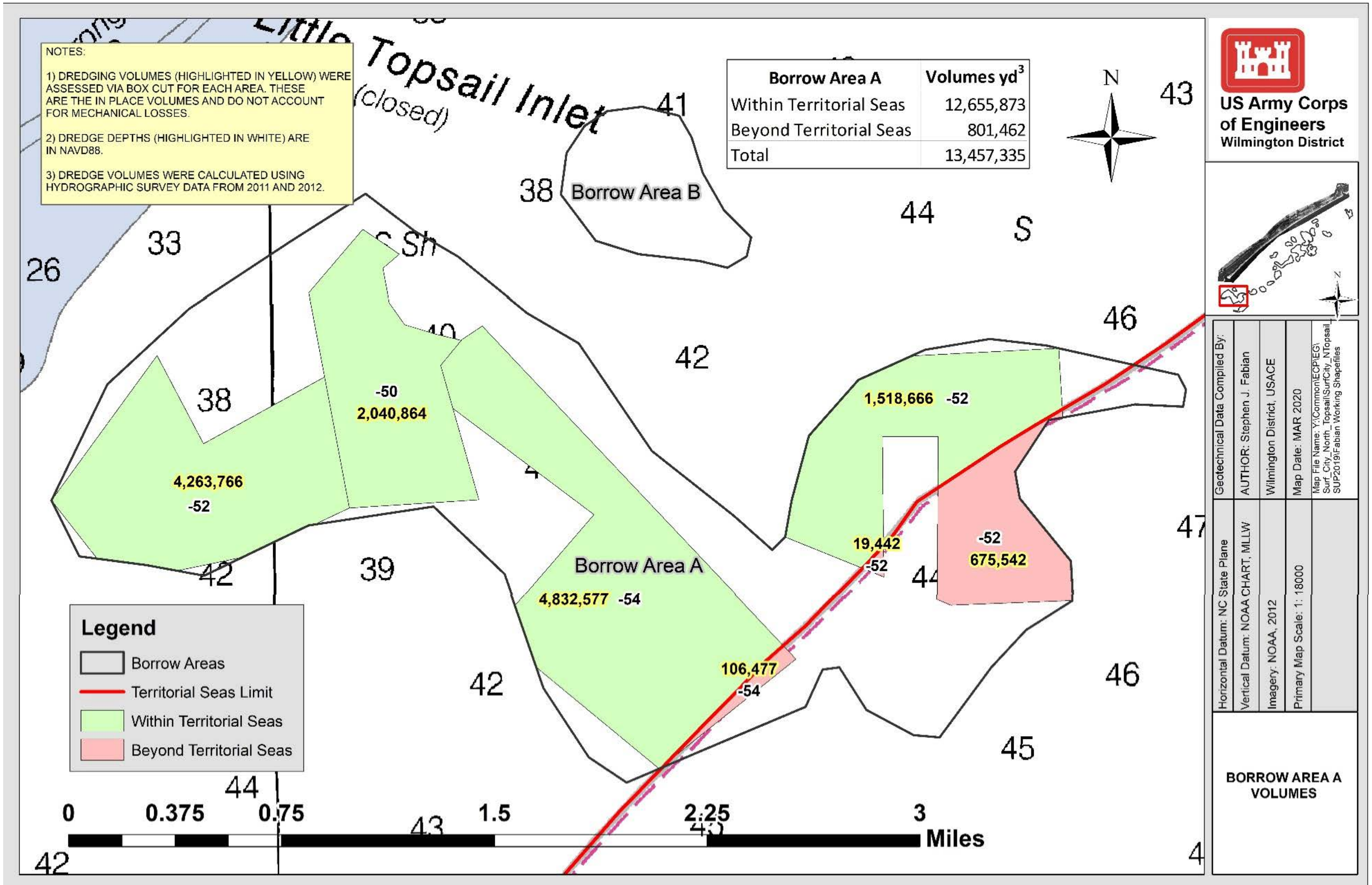


Figure 61. Borrow Area A dredge cut boxes and available volumes within and beyond the territorial sea limit (3 nautical mile line).

Table 5. Estimated Borrow Area Volumes.

Borrow Area	Feasibility (cubic yards)	PED Phase II 2013 (cubic yards)	PED Phase II 2020 (cubic yards)	+3 Nautical Miles (cubic yards)	-3 Nautical Miles (cubic yards)
Borrow Area A	13,200,000	14,444,000	13,457,335	801,462	12,655,873
Borrow Area B	820,000	820,000*	820,000*	0	820,000*
Borrow Area C	2,570,000	2,570,000*	2,570,000*	2,570,000*	0
Borrow Area D	1,860,000	1,860,000*	1,860,000*	1,860,000*	0
Borrow Area E	Excluded	Eliminated	0	0	0
Borrow Area F	Excluded	Eliminated	0	0	0
Borrow Area G	2,410,000	2,830,300	2,642,798	2,642,798	0
Borrow Area H	720,000	1,424,640	1,428,988	1,428,988	0
Borrow Area J	3,670,000	1,664,110	1,641,596	1,506,277	135,319
Borrow Area L	6,130,000	3,544,870	3,616,546	2,243,947	1,372,599
Borrow Area N	5,640,000	2,547,080	2,539,483	2,539,483	0
Borrow Area O	3,850,000	7,010,310	7,053,742	793,931	6,259,811
Borrow Area P	2,730,000	3,414,390	3,395,655	0	3,395,655
Borrow Area Q	730,000	6,551,300[8]	Eliminated[9]	0	0
Borrow Area R	Excluded	Eliminated	0	0	0
Borrow Area S	1,460,000	Eliminated	0		
Borrow Area T	250,000	Eliminated	0		
Total	**46,770,000**	**43,431,000**	**35,776,143**	**11,956,886**	**23,819,257**

*Values not representative of design level volumes and were not included in total PED volumes listed.

[8] Volume reported by CPE in the non-federal 2007 investigation, Fink et al. (2007).

[9] In 2015, 1,300,000 cubic yards was placed as beach nourishment by the Town of Topsail Beach. Additional available volumes would require further analysis with a tighter grid-spacing.

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15A NCAC 07H .0312, 2007, "Technical standards for beach fill projects." http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2007%20-%20coastal%20management/subchapter%20h/15a%20ncac%2007h%20.0312.pdf

Addendum A-1: Geotechnical Data

Available Upon Request

Includes Boring Logs, Laboratory Test Results, and Previous Reports

The following reports are available:

- HDR Engineering, Inc., 2002. An Assessment of the Availability of Beachfill Quality Sand Offshore Topsail Beach, Pender County, NC, Project Report for the U.S. Army Corps of Engineers, Wilmington District, 28p.
- HDR Engineering, Inc., 2003. An Assessment of the Availability of Beachfill Quality Sand Offshore North Topsail Beach and Surf City, North Carolina, Project Report for the U.S. Army Corps of Engineers, Wilmington District, 41p.
- Ocean Surveys, Inc., 2004. Marine geophysical investigation for the evaluation of sand resource areas offshore Topsail Island, North Carolina: Final report prepared for the U.S. Army Corps of Engineers Wilmington District, 44p.
- Athena Technologies. 2013. RE: RFQ #W912PM-13-T-0024 Vibracore Sampling and Soils Lab Testing of Offshore Borrow Sources, Surf City and North Topsail Beach, North Carolina. 02 July 2013.
- USACE Wilmington District, 2013. Geotechnical Appendix – West Onslow Beach and New River Inlet (Topsail Beach), NC, Coastal Storm Damage Reduction Project.
- Athena Technologies. 2014. Site Conditions and Laboratory Report, Vibracore Sampling and Soils Lab Testing of Offshore Borrow Sources, Surf City and North Topsail Beach, North Carolina. Contract #W912PM-13-T-0024. July 2013.

Addendum A-2: Composite Borings Results

Composite boring results using the state methods are listed first and results using USACE methods are listed second. Please see Section 5 Subsurface Investigation Results, Compatibility Analysis Page 76, for a description of these methods.

Composite results based on the state standard

Table A-2- 1. Results from the 2003 and 2011 USACE borings within Borrow Site G.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-254	2.00	2.45	0.43	1.63	3.00	99.67	4.91	0.85
TI-03-V-256	2.00	2.09	0.62	1.06	7.00	97.20	4.18	1.24
TI-03-V-257	3.00	2.42	0.93	9.68	7.50	95.76	7.26	2.80
TI-03-V-258	1.30	1.31	1.83	1.23	18.00	84.15	1.70	2.38
TI-03-V-275	5.50	2.58	0.43	6.35	3.67	98.39	14.20	2.38
SC-11-V-189	2.70	1.17	0.97	1.36	5.00	92.94	3.16	2.61
SC-11-V-190	0.80	2.22	0.62	2.16	4.00	97.77	1.78	0.49
SC-11-V-191	1.70	2.12	0.66	1.68	5.00	97.83	3.61	1.12
SC-11-V-192	0.60	2.02	0.81	5.66	6.00	94.75	1.21	0.49
SC-11-V-193	0.00	-	-	-	-	-	-	-
SC-11-V-194	5.40	2.46	0.46	2.26	2.00	98.92	13.29	2.50
SC-11-V-195	1.20	2.43	0.48	1.85	4.00	97.86	2.92	0.57
SC-11-V-196	0.50	1.66	1.20	3.35	16.00	89.66	0.83	0.60
SC-11-V-197	5.00	2.45	0.52	9.05	1.00	99.85	12.24	2.58
SC-11-V-198	2.50	1.76	1.27	5.04	9.20	88.69	4.40	3.17
SC-11-V-199	2.00	2.38	0.55	4.63	2.00	98.53	4.76	1.09
SC-11-V-200	1.10	2.31	0.56	2.24	2.00	99.21	2.55	0.62
SC-11-V-201	4.00	2.36	0.50	2.74	2.00	98.98	9.45	1.99
SC-11-V-202	5.50	1.96	1.00	6.09	6.45	91.81	10.79	5.50
SC-11-V-203	8.00	2.45	0.50	1.92	1.75	99.23	19.60	3.98
SC-11-V-204	7.80	2.11	0.74	2.53	6.51	96.13	16.43	5.74
SC-11-V-205	4.40	2.34	0.72	5.12	2.50	99.39	10.28	3.17
SC-11-V-206	9.00	2.56	0.44	4.33	1.56	99.19	23.04	3.93
SC-11-V-207	7.50	2.31	0.62	3.26	5.20	96.73	17.35	4.67
SC-11-V-208	10.00	2.67	0.35	6.10	1.20	99.53	26.65	3.52
SC-11-V-209	5.00	2.15	1.02	5.29	10.00	86.98	10.74	5.11
SC-11-V-210	5.10	0.60	3.43	10.01	1.55	76.25	3.04	17.49
SC-11-V-211	8.10	2.56	0.38	3.09	2.88	97.90	20.73	3.05
SC-11-V-212	1.50	2.16	0.58	1.43	3.00	98.75	3.23	0.88
SC-11-V-213	6.80	2.15	0.87	5.34	3.00	98.53	14.65	5.89
SC-11-V-214	6.60	2.51	0.44	4.57	2.73	97.67	16.57	2.87
Totals	126.6	64.7	23.9	121.0	145.7	2868.3	285.6	93.3

Borrow Site G Composite Data

Mean (phi)	**2.26**
Std Dev (phi)	**0.74**
Weight % Fines passing #230	**4.47**
Visual % Shell	**3.80**
Weight % Pass #10	**96.20**

Table A-2- 2. Results from the 2003 and 2011 USACE borings within Borrow Site H.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-260	2.20	2.07	0.87	3.56	11.00	93.33	4.55	1.91
TI-03-V-273	4.80	2.27	0.55	2.14	5.44	97.85	10.89	2.64
SC-11-V-181	1.10	2.26	0.59	1.24	4.00	98.19	2.48	0.65
SC-11-V-182	8.90	2.54	0.39	3.35	1.56	99.52	22.64	3.46
SC-11-V-183	8.70	2.37	0.55	2.95	4.86	97.21	20.59	4.74
SC-11-V-184	1.40	1.89	1.11	2.10	4.00	89.24	2.65	1.55
SC-11-V-185	11.00	2.56	0.44	5.98	2.37	99.20	28.18	4.79
SC-11-V-186	20.00	2.57	0.36	2.01	1.15	99.79	51.37	7.21
SC-11-V-187	0.00	-	-	-	-	-	-	-
SC-11-V-188	4.00	2.25	0.60	1.96	2.00	98.59	9.00	2.38
Totals	62.1	20.8	5.4	25.3	36.4	872.9	152.3	29.3

Borrow Site H Composite Data

Mean (phi)	**2.45**
Std Dev (phi)	**0.47**
Weight % Fines passing #230	**3.09**
Visual % Shell	**2.80**
Weight % Pass #10	**98.60**

Table A-2- 3. Results from the 2003 and 2011 USACE borings within Borrow Site J.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-98	2.80	2.13	0.73	5.15	11.00	98.23	5.98	2.03
TI-03-V-99	3.30	2.46	0.44	9.65	6.00	98.58	8.10	1.47
TI-03-V-101	1.50	1.69	1.16	1.42	21.00	93.07	2.53	1.74
TI-03-V-102	3.00	1.86	1.05	2.34	16.33	94.19	5.59	3.16
TI-03-V-103	2.60	2.29	0.58	2.82	10.00	98.23	5.95	1.51
TI-03-V-270A	2.00	2.00	0.81	1.46	9.00	95.90	4.01	1.62
TI-03-V-283	3.20	1.87	0.88	2.13	8.50	94.48	5.97	2.83
TI-03-V-286	2.20	1.89	0.90	2.56	11.00	94.80	4.16	1.99
SC-11-V-132	0.00	-	-	-	-	-	-	-
SC-11-V-133	1.30	2.13	0.75	3.19	8.00	96.57	2.77	0.98
SC-11-V-134	4.00	2.17	0.62	2.07	3.00	99.04	8.69	2.50
SC-11-V-135	1.70	2.30	0.49	1.42	2.00	99.38	3.91	0.83
SC-11-V-136	3.40	2.02	1.15	11.44	7.00	91.96	6.85	3.92
SC-11-V-137	0.00	-	-	-	-	-	-	-
SC-11-V-138	0.00	-	-	-	-	-	-	-
SC-11-V-139	2.20	2.08	0.77	1.26	6.00	95.94	4.57	1.70
SC-11-V-140	1.20	2.33	0.47	1.75	2.00	97.56	2.79	0.57
SC-11-V-141	0.00	-	-	-	-	-	-	-
SC-11-V-142	3.30	-0.02	2.74	1.15	31.00	67.79	-0.07	9.04
SC-11-V-143	3.00	2.36	0.52	1.14	4.00	98.84	7.08	1.56
SC-11-V-144	3.30	2.45	0.44	1.66	3.00	98.99	8.09	1.44
SC-11-V-146	1.00	2.42	0.41	2.05	2.00	99.35	2.42	0.41
SC-11-V-147	2.00	1.08	1.63	1.02	21.00	86.52	2.16	3.26
SC-11-V-148	1.50	1.85	1.27	5.37	8.00	87.80	2.77	1.90
SC-11-V-149	4.00	2.59	0.58	6.29	4.00	97.26	10.37	2.34
SC-11-V-150	4.00	2.51	0.56	5.64	2.00	98.64	10.03	2.25
SC-11-V-151	0.80	2.23	0.67	2.98	6.00	98.08	1.78	0.53
SC-11-V-152	0.00	-	-	-	-	-	-	-
SC-11-V-153	2.00	0.74	2.11	3.10	27.50	75.44	1.48	4.23
SC-11-V-154	0.00	-	-	-	-	-	-	-
SC-11-V-155	1.10	2.35	0.47	1.83	4.00	97.99	2.59	0.52
SC-11-V-156	2.10	2.26	0.49	1.49	3.00	97.99	4.75	1.02
SC-11-V-157	0.00	-	-	-	-	-	-	-
SC-11-V-158	0.00	-	-	-	-	-	-	-
SC-11-V-159	2.30	1.10	1.63	0.95	14.00	85.11	2.52	3.74
SC-11-V-161	1.40	0.56	1.94	0.97	38.00	78.62	0.78	2.72
SC-11-V-162	1.50	1.94	1.02	2.28	5.00	94.88	2.91	1.54

continued

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
SC-11-V-163	2.50	2.45	0.41	1.75	2.00	99.17	6.12	1.03
SC-11-V-164	2.00	2.34	0.49	1.52	3.00	99.37	4.69	0.97
SC-11-V-165	2.80	2.42	0.43	1.55	3.00	99.17	6.79	1.20
SC-11-V-166	3.00	2.01	0.89	1.43	9.00	95.78	6.02	2.66
SC-11-V-167	2.60	2.78	0.78	13.10	7.00	95.09	7.23	2.04
SC-11-V-169	3.10	2.25	0.47	1.24	2.00	99.55	6.96	1.45
SC-11-V-170	1.60	2.49	0.40	5.83	1.00	99.84	3.98	0.64
SC-11-V-171	0.00	-	-	-	-	-	-	-
SC-11-V-172	2.60	2.20	0.62	1.34	6.00	96.62	5.72	1.62
SC-11-V-173	0.00	-	-	-	-	-	-	-
SC-11-V-174	1.50	2.16	0.60	1.17	3.00	99.02	3.24	0.90
SC-11-V-175	0.00	-	-	-	-	-	-	-
SC-11-V-176	0.00	-	-	-	-	-	-	-
SC-11-V-177	1.80	2.28	0.87	13.06	11.00	93.66	4.10	1.57
SC-11-V-178	3.40	1.21	1.38	2.39	14.00	91.95	4.11	4.70
SC-11-V-179	0.00	-	-	-	-	-	-	-
SC-11-V-180	1.80	1.81	0.90	1.13	9.00	96.01	3.25	1.61
Totals	96.4	82.0	35.5	132.1	363.3	3876.5	193.8	83.7

Borrow Site J Composite Data

Mean (phi)	**2.45**
Std Dev (phi)	**0.47**
Weight % Fines passing #230	**3.09**
Visual % Shell	**2.80**
Weight % Pass #10	**98.6**

Table A-2- 4. Results from the 2003 and 2011 USACE borings within Borrow Site L.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-89	2.00	1.87	0.96	7.19	2.00	93.61	3.74	1.91
TI-03-V-90	0.50	0.79	1.28	1.44	19.00	85.07	0.40	0.64
TI-03-V-91	3.00	1.71	1.51	6.62	18.40	86.95	5.14	4.52
TI-03-V-93	2.30	2.15	0.83	8.48	15.00	95.40	4.94	1.90
TI-03-V-95	3.00	2.49	0.45	9.76	8.00	98.06	7.46	1.34
TI-03-V-96	3.20	1.30	1.40	3.01	11.94	90.33	4.16	4.47
TI-03-V-341	4.30	2.12	0.88	6.34	6.07	96.76	9.10	3.77
TI-03-V-342	2.00	1.89	1.04	3.75	15.00	91.58	3.77	2.07
TI-03-V-343	5.00	2.37	0.50	3.28	3.00	98.57	11.84	2.50
TI-03-V-344	2.30	0.81	2.23	1.58	22.22	79.18	1.86	5.13
TI-03-V-345	3.00	1.65	1.01	1.75	15.07	95.09	4.95	3.02
TI-03-V-346	1.50	1.74	1.14	3.63	13.00	92.31	2.60	1.71
TI-03-V-351	1.00	-0.43	2.67	2.21	28.00	57.50	-0.43	2.67
SC-11-V-68	1.90	2.13	0.58	1.26	4.00	98.38	4.04	1.11
SC-11-V-69	0.00	-	-	-	-	-	-	-
SC-11-V-70	1.90	2.16	0.66	1.85	4.00	98.01	4.11	1.26
SC-11-V-71	1.20	2.28	0.56	3.10	2.00	99.12	2.74	0.67
SC-11-V-72	3.00	2.54	0.58	9.44	6.00	97.89	7.62	1.75
SC-11-V-73	1.00	2.20	0.53	1.87	2.00	98.13	2.20	0.53
SC-11-V-74	1.40	2.05	0.53	1.34	2.00	99.08	2.87	0.74
SC-11-V-75	0.00	-	-	-	-	-	-	-
SC-11-V-76	1.00	2.03	0.72	1.56	5.00	95.50	2.03	0.72
SC-11-V-77	0.00	-	-	-	-	-	-	-
SC-11-V-78	5.40	1.67	1.38	6.37	14.43	91.24	9.02	7.44
SC-11-V-79	2.80	1.66	1.44	10.05	16.00	90.94	4.65	4.03
SC-11-V-80	0.50	0.99	2.09	7.73	18.00	80.55	0.50	1.04
SC-11-V-81	1.30	2.12	0.70	1.24	5.00	96.47	2.75	0.92
SC-11-V-82	0.80	1.84	1.23	7.98	3.00	92.28	1.47	0.99
SC-11-V-83	6.00	1.92	1.12	6.11	10.80	91.68	11.51	6.73
SC-11-V-84	0.60	0.14	2.02	1.32	30.00	76.77	0.08	1.21
SC-11-V-85	1.70	1.92	0.77	1.06	5.00	98.06	3.27	1.31
SC-11-V-86	3.80	1.60	1.36	5.66	19.32	92.30	6.09	5.17
SC-11-V-87	2.40	2.08	0.77	1.54	9.12	97.00	4.98	1.85
SC-11-V-88	2.00	2.37	0.62	4.67	5.70	98.09	4.74	1.25
SC-11-V-89	2.70	2.22	0.63	2.61	4.00	99.24	6.00	1.71
SC-11-V-90	0.00	-	-	-	-	-	-	-
SC-11-V-91	0.80	2.21	0.63	1.31	4.00	97.23	1.76	0.50

								continued
Boring Number	**Thickness (ft)**	**Mean (phi)**	**Std Dev (phi)**	**Weight % Fines (passing #230)**	**Visual % Shell**	**Weight % Passing #10**	**Weighted Mean**	**Weighted Std Dev**
SC-11-V-92	1.20	2.03	0.79	1.46	5.00	97.22	2.44	0.95
SC-11-V-93	2.20	1.94	0.72	1.45	5.00	97.25	4.28	1.58
SC-11-V-94	0.00	-	-	-	-	-	-	-
SC-11-V-95	7.90	1.46	1.66	1.42	12.52	87.48	11.51	13.11
SC-11-V-96	3.50	0.38	2.60	1.45	34.40	74.08	1.31	9.09
SC-11-V-97	2.10	1.64	1.26	1.84	12.00	91.77	3.44	2.65
SC-11-V-98	0.00	-	-	-	-	-	-	-
SC-11-V-99	0.00	-	-	-	-	-	-	-
SC-11-V-100	0.90	1.97	0.86	1.14	6.00	94.29	1.77	0.78
SC-11-V-101	0.00	-	-	-	-	-	-	-
SC-11-V-102	4.00	0.45	2.63	1.71	27.00	76.18	1.80	10.52
SC-11-V-103	5.20	1.52	1.42	1.33	10.62	87.12	7.92	7.40
SC-11-V-104	0.30	1.55	0.69	1.14	7.00	93.37	0.47	0.21
SC-11-V-105	0.00	-	-	-	-	-	-	-
SC-11-V-106	0.00	-	-	-	-	-	-	-
SC-11-V-107	4.40	0.00	3.05	1.66	39.00	65.98	-0.01	13.40
SC-11-V-108	2.00	2.10	0.91	5.54	4.20	91.21	4.20	1.82
SC-11-V-109	0.00	-	-	-	-	-	-	-
SC-11-V-110	0.00	-	-	-	-	-	-	-
SC-11-V-111	2.00	2.20	0.88	5.97	9.00	91.65	4.41	1.77
SC-11-V-112	0.00	-	-	-	-	-	-	-
SC-11-V-113	0.00	-	-	-	-	-	-	-
SC-11-V-114	0.60	1.82	1.34	10.97	10.00	91.80	1.09	0.81
SC-11-V-115	2.80	1.35	1.94	9.74	16.00	84.33	3.79	5.42
SC-11-V-116	2.70	1.33	1.53	1.50	9.00	87.97	3.60	4.12
SC-11-V-117	0.00	-	-	-	-	-	-	-
SC-11-V-118	1.20	2.21	0.53	1.09	2.00	98.74	2.65	0.64
SC-11-V-119	2.00	0.13	2.48	1.17	19.00	70.72	0.27	4.95
SC-11-V-120	0.00	-	-	-	-	-	-	-
SC-11-V-121	4.00	2.49	0.69	5.84	4.50	97.60	9.96	2.77
SC-11-V-122	0.00	-	-	-	-	-	-	-
SC-11-V-123	0.90	0.16	2.55	1.26	28.00	70.67	0.14	2.30
SC-11-V-124	0.00	-	-	-	-	-	-	-
SC-11-V-125	2.00	0.93	1.35	1.14	4.00	86.25	1.86	2.70
SC-11-V-126	0.00	-	-	-	-	-	-	-
SC-11-V-129	0.00	-	-	-	-	-	-	-
SC-11-V-130	1.80	0.59	2.17	1.32	17.00	73.93	1.06	3.90
SC-11-V-131	2.40	1.85	0.89	1.23	3.00	96.06	4.44	2.12

continued

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
Totals	131.4	88.7	67.8	198.5	630.3	4954.0	214.4	169.6

Borrow Site L Composite Data

Mean (phi)	**1.63**
Std Dev (phi)	**1.29**
Weight % Fines passing #230	**3.84**
Visual % Shell	**12.30**
Weight % Pass #10	**90.00**

Table A-2- 5. Results from the 2003 and 2013 USACE borings within Borrow Site N.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
SC-13-V-01	7.40	2.19	0.53	2.37	10.86	96.36	16.22	3.93
SC-13-V-03	5.90	2.21	0.64	3.89	12.40	96.25	13.06	3.79
SC-13-V-14	6.10	2.24	0.57	3.45	9.41	95.18	13.68	3.50
SC-13-V-20	4.40	1.46	1.52	2.25	27.18	86.27	6.42	6.67
SC-13-V-21	7.30	2.42	0.53	3.97	5.48	97.73	17.65	3.84
SC-13-V-22	8.70	2.33	0.34	2.79	6.17	97.23	20.30	2.96
SC-13-V-24	8.40	2.37	0.44	1.57	8.81	94.38	19.95	3.72
SC-13-V-25	8.50	2.30	0.59	1.90	9.40	96.18	19.54	4.98
SC-13-V-26	5.70	2.19	0.52	3.35	4.83	99.32	12.46	2.94
SC-13-V-28	10.00	1.34	1.23	1.97	27.64	91.52	13.40	12.26
TI-03-V-65	4.80	2.37	0.43	1.58	7.25	98.67	11.36	2.08
TI-03-V-69	4.50	1.21	1.87	1.29	25.87	83.74	5.45	8.43
Totals	164.1	38.5	11.8	30.4	53.3	1632.2	380.9	108.1

Borrow Site N Composite Data	
Mean (phi)	**2.07**
Std Dev (phi)	**0.72**
Weight % Fines passing #230	**2.52**
Visual % Shell	**12.65**
Weight % Pass #10	**94.77**

Table A-2- 6. Results from the 2003 and 2011 USACE borings within Borrow Site O.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-82	2.50	2.35	0.58	5.42	5.00	99.59	5.87	1.45
TI-03-V-8in add	5.10	0.33	2.98	8.24	45.59	66.49	1.70	15.19
TI-03-V-85	7.10	2.07	0.83	6.36	5.56	92.04	14.67	5.89
TI-03-V-316	2.70	1.62	1.37	2.81	17.00	91.13	4.38	3.70
TI-03-V-322	3.10	2.51	0.44	7.09	3.00	99.30	7.78	1.37
TI-03-V-323	4.90	2.07	0.79	4.83	8.61	95.94	10.13	3.85
TI-03-V-324	7.00	1.85	1.22	5.41	8.80	86.92	12.98	8.57
TI-03-V-325	2.00	2.31	0.59	4.50	9.00	95.34	4.63	1.18
TI-03-V-326	12.70	2.54	0.43	5.32	1.16	99.77	32.21	5.47
TI-03-V-327	4.00	2.22	0.76	5.86	11.00	93.34	8.87	3.04
SC-11-V-22	20.10	2.52	0.43	5.81	1.00	99.76	50.64	8.61
SC-11-V-23	1.20	0.01	3.53	2.53	15.00	63.53	0.01	4.24
SC-11-V-24	1.70	0.13	2.85	1.13	22.00	64.14	0.22	4.84
SC-11-V-25	0.00	-	-	-	-	-	-	-
SC-11-V-26	0.00	-	-	-	-	-	-	-
SC-11-V-27	1.80	2.43	0.51	5.48	3.00	99.04	4.37	0.92
SC-11-V-28	3.00	2.49	0.45	7.50	2.00	99.32	7.46	1.36
SC-11-V-29	3.70	2.48	0.47	9.26	3.00	97.72	9.18	1.73
SC-11-V-30	0.00	-	-	-	-	-	-	-
SC-11-V-31	0.00	-	-	-	-	-	-	-
SC-11-V-32	3.50	2.49	0.40	7.17	1.00	99.62	8.73	1.42
SC-11-V-33	4.10	2.00	0.88	4.79	5.41	94.83	8.21	3.63
SC-11-V-34	6.70	2.39	0.47	5.58	1.40	99.42	16.03	3.16
SC-11-V-35	17.60	2.48	0.42	4.46	1.00	99.83	43.65	7.43
SC-11-V-36	3.00	2.45	0.46	6.70	3.80	96.35	7.34	1.37
SC-11-V-37	5.00	2.47	0.44	6.49	1.64	99.57	12.36	2.18
SC-11-V-38	3.30	2.41	0.46	4.97	4.00	97.43	7.96	1.51
SC-11-V-39	10.70	2.61	0.40	5.77	1.00	99.91	27.92	4.24
SC-11-V-40	3.00	2.48	0.40	7.02	1.00	99.79	7.43	1.21
SC-11-V-41	6.00	2.20	0.78	7.92	9.40	91.25	13.21	4.67
SC-11-V-42	7.00	2.35	0.62	8.85	1.00	93.06	16.48	4.32
SC-11-V-43	5.00	1.87	1.04	6.47	8.28	91.54	9.35	5.22
SC-11-V-44	8.70	0.74	2.56	1.63	18.62	77.77	6.42	22.26
SC-11-V-45	9.50	2.43	0.44	6.71	1.53	97.80	23.11	4.16
SC-11-V-46	7.50	2.31	0.52	5.94	1.31	97.86	17.34	3.89
SC-11-V-47	9.60	2.49	0.43	8.62	1.14	97.51	23.90	4.12
SC-11-V-48	0.00	-	-	-	-	-	-	-

continued

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
SC-11-V-49	0.00	-	-	-	-	-	-	-
SC-11-V-50	0.00	-	-	-	-	-	-	-
SC-11-V-51	1.50	0.41	2.56	1.16	10.00	73.61	0.62	3.84
SC-11-V-52	10.90	2.17	0.62	4.45	4.18	94.95	23.65	6.71
SC-11-V-53	0.00	-	-	-	-	-	-	-
SC-11-V-54	0.00	-	-	-	-	-	-	-
SC-11-V-55	0.00	-	-	-	-	-	-	-
SC-11-V-56	0.00	-	-	-	-	-	-	-
SC-11-V-57	2.30	2.03	0.56	2.64	2.00	96.48	4.66	1.28
SC-11-V-58	0.50	1.87	1.37	10.07	16.00	86.13	0.94	0.68
SC-11-V-59	2.00	2.04	0.87	5.84	7.00	95.59	4.09	1.74
SC-11-V-60	0.40	0.90	2.61	4.39	21.00	79.38	0.36	1.04
SC-11-V-61	0.40	1.84	1.09	1.87	14.00	86.96	0.74	0.44
SC-11-V-62	1.10	1.99	0.71	1.32	9.00	93.85	2.18	0.78
SC-11-V-63	0.00	-	-	-	-	-	-	-
SC-11-V-64	5.00	2.22	0.58	2.08	2.60	98.85	11.12	2.90
SC-11-V-65	6.00	2.40	0.53	2.16	4.33	96.67	14.38	3.17
SC-11-V-66	2.00	1.85	1.11	7.76	3.60	95.26	3.69	2.21
SC-11-V-67	4.10	1.91	0.92	2.10	9.80	89.97	7.84	3.77
Totals	229.0	87.7	42.5	232.5	325.8	4064.6	498.8	174.8

Borrow Site O Composite Data

Mean (phi)	**2.18**
Std Dev (phi)	**0.76**
Weight % Fines passing #230	**5.52**
Visual % Shell	**5.30**
Weight % Pass #10	**94.80**

Table A-2- 7. Results from the 2003 and 2011 USACE borings within Borrow Site P.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #230)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-317	4.00	1.34	2.00	6.20	12.18	83.63	5.34	8.00
TI-03-V-320	10.50	2.23	0.66	5.90	5.93	91.48	23.44	6.95
SC-11-V-1	3.00	2.53	0.43	8.64	3.00	97.52	7.58	1.29
SC-11-V-2	3.00	2.31	0.59	5.27	1.00	99.34	6.94	1.78
SC-11-V-3	3.00	1.44	1.81	5.91	7.67	85.27	4.32	5.44
SC-11-V-4	3.00	2.14	0.94	9.36	3.00	94.60	6.41	2.81
SC-11-V-5	0.00	-	-	-	-	-	-	-
SC-11-V-6	0.00	-	-	-	-	-	-	-
SC-11-V-7	0.00	-	-	-	-	-	-	-
SC-11-V-8	3.00	2.15	0.62	4.82	3.27	98.78	6.45	1.87
SC-11-V-9	3.00	2.30	0.52	4.93	1.63	99.14	6.90	1.56
SC-11-V-10	6.00	2.19	0.74	5.81	2.67	97.74	13.15	4.43
SC-11-V-11	5.90	2.28	0.65	5.29	3.54	97.82	13.44	3.84
SC-11-V-12	0.00	-	-	-	-	-	-	-
SC-11-V-13	0.00	-	-	-	-	-	-	-
SC-11-V-14	3.50	2.43	0.43	5.71	1.00	99.00	8.52	1.50
SC-11-V-15	3.00	2.48	0.41	7.35	1.00	99.82	7.45	1.23
SC-11-V-16	0.00	-	-	-	-	-	-	-
SC-11-V-17	3.00	2.17	0.51	3.84	2.00	99.06	6.51	1.53
SC-11-V-18	3.00	2.44	0.48	11.76	1.00	96.72	7.31	1.45
SC-11-V-19	3.00	2.31	0.57	6.97	1.00	97.34	6.93	1.70
SC-11-V-20	6.00	2.41	0.45	8.52	1.00	97.49	14.46	2.68
SC-11-V-21	5.70	0.26	2.23	1.21	12.33	74.22	1.47	12.69
Totals	71.6	35.4	14.0	107.5	63.2	1609.0	146.6	60.7

Borrow Site P Composite Data

Mean (phi)	**2.05**
Std Dev (phi)	**0.85**
Weight % Fines passing #230	**6.11**
Visual % Shell	**4.21**
Weight % Pass #10	**93.80**

Composite results based on USACE practice

Table A-2- 8. Results from the 2003 and 2011 USACE borings within Borrow Site G.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-254	5.00	2.09	0.90	8.00	5.00	92.73	10.46	4.50
TI-03-V-256	2.00	2.09	0.62	1.18	7.00	97.20	4.18	1.24
TI-03-V-257	3.00	2.42	0.93	11.67	7.50	95.76	7.26	2.80
TI-03-V-258	2.80	0.89	2.48	3.13	28.18	77.42	2.50	6.95
TI-03-V-275	5.50	2.58	0.43	7.19	3.67	98.39	14.20	2.38
SC-11-V-189	2.70	1.17	0.97	1.39	5.00	92.94	3.16	2.61
SC-11-V-190	4.50	1.92	1.57	10.94	2.07	87.79	8.65	7.06
SC-11-V-191	1.70	2.12	0.66	1.72	5.00	97.83	3.61	1.12
SC-11-V-192	0.60	2.02	0.81	5.87	6.00	94.75	1.21	0.49
SC-11-V-193	0.00	-	-	-	-	-	-	-
SC-11-V-194	7.30	2.40	0.56	4.97	1.74	96.46	17.52	4.06
SC-11-V-195	1.20	2.43	0.48	1.92	4.00	97.86	2.92	0.57
SC-11-V-196	0.50	1.66	1.20	3.45	16.00	89.66	0.83	0.60
SC-11-V-197	5.00	2.45	0.52	9.70	1.00	99.85	12.24	2.58
SC-11-V-198	6.20	1.02	2.33	8.65	6.10	80.34	6.32	14.44
SC-11-V-199	2.00	2.38	0.55	4.86	2.00	98.53	4.76	1.09
SC-11-V-200	1.10	2.31	0.56	2.33	2.00	99.21	2.55	0.62
SC-11-V-201	4.00	2.36	0.50	2.83	2.00	98.98	9.45	1.99
SC-11-V-202	7.00	1.79	1.25	7.35	5.29	89.24	12.55	8.76
SC-11-V-203	8.00	2.45	0.50	2.26	1.75	99.23	19.60	3.98
SC-11-V-204	9.70	2.09	0.80	4.43	6.22	94.34	20.26	7.76
SC-11-V-205	4.40	2.34	0.72	5.97	2.50	99.39	10.28	3.17
SC-11-V-206	9.00	2.56	0.44	4.67	1.56	99.19	23.04	3.93
SC-11-V-207	7.50	2.31	0.62	3.45	5.20	96.73	17.35	4.67
SC-11-V-208	10.00	2.67	0.35	6.67	1.20	99.53	26.65	3.52
SC-11-V-209	5.00	2.15	1.02	5.82	10.00	86.98	10.74	5.11
SC-11-V-210	5.10	0.60	3.43	10.57	1.55	76.25	3.04	17.49
SC-11-V-211	8.10	2.56	0.38	3.32	2.88	97.90	20.73	3.05
SC-11-V-212	1.50	2.16	0.58	1.49	3.00	98.75	3.23	0.88
SC-11-V-213	6.80	2.15	0.87	5.64	3.00	98.53	14.65	5.89
SC-11-V-214	6.60	2.51	0.44	4.78	2.73	97.67	16.57	2.87
Totals	125.5	52.6	22.1	125.1	99.8	2367.9	271.9	108.3

Borrow Site G Composite Data

Mean (phi)	**2.17**
Std Dev (phi)	**0.86**
Weight % Fines passing #200	**5.43**
Visual % Shell	**3.42**
Weight % Pass #10	**94.81**

Table A-2- 9. Results from the 2003 and 2011 USACE borings within Borrow Site H.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-260	2.20	2.07	0.87	3.91	11.00	93.33	4.55	1.91
TI-03-V-273	11.00	2.50	0.42	3.06	3.25	98.94	27.54	4.67
SC-11-V-181	1.10	2.26	0.59	1.28	4.00	98.19	2.48	0.65
SC-11-V-182	8.90	2.54	0.39	3.55	1.56	99.52	22.64	3.46
SC-11-V-183	8.70	2.37	0.55	3.13	4.86	97.21	20.59	4.74
SC-11-V-184	1.40	1.89	1.11	2.36	4.00	89.24	2.65	1.55
SC-11-V-185	11.00	2.56	0.44	6.49	2.37	99.20	28.18	4.79
SC-11-V-186	20.00	2.57	0.36	2.15	1.15	99.79	51.37	7.21
SC-11-V-187	0.00	-	-	-	-	-	-	-
SC-11-V-188	4.00	2.25	0.60	2.05	2.00	98.59	9.00	2.38
Totals	55.1	16.4	4.0	21.0	19.9	681.7	136.9	24.8

Borrow Site H Composite Data

Mean (phi)	**2.48**
Std Dev (phi)	**0.45**
Weight % Fines passing #200	**3.38**
Visual % Shell	**2.24**
Weight % Pass #10	**98.83**

Table A-2- 10. Results from the 2003 and 2011 USACE borings within Borrow Site J.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-98	2.80	2.13	0.73	5.33	11.00	98.23	5.98	2.03
TI-03-V-99	8.30	2.45	0.44	9.72	6.24	98.42	20.32	3.67
TI-03-V-101	1.50	1.69	1.16	1.52	21.00	93.07	2.53	1.74
TI-03-V-102	3.00	1.86	1.05	2.51	16.33	94.19	5.59	3.16
TI-03-V-103	2.60	2.29	0.58	3.00	10.00	98.23	5.95	1.51
TI-03-V-270A	2.00	2.00	0.81	1.70	9.00	95.90	4.01	1.62
TI-03-V-283	3.20	1.87	0.88	2.23	8.50	94.48	5.97	2.83
TI-03-V-286	4.00	1.85	1.15	7.20	13.70	88.75	7.39	4.62
SC-11-V-132	0.00	-	-	-	-	-	-	-
SC-11-V-133	1.30	2.13	0.75	3.29	8.00	96.57	2.77	0.98
SC-11-V-134	4.00	2.17	0.62	2.16	3.00	99.04	8.69	2.50
SC-11-V-135	1.70	2.30	0.49	1.47	2.00	99.38	3.91	0.83
SC-11-V-136	3.40	2.02	1.15	11.82	7.00	91.96	6.85	3.92
SC-11-V-137	0.00	-	-	-	-	-	-	-
SC-11-V-138	0.00	-	-	-	-	-	-	-
SC-11-V-139	2.20	2.08	0.77	1.32	6.00	95.94	4.57	1.70
SC-11-V-140	1.20	2.33	0.47	1.83	2.00	97.56	2.79	0.57
SC-11-V-141	0.00	-	-	-	-	-	-	-
SC-11-V-142	3.30	-0.02	2.74	1.20	31.00	67.79	-0.07	9.04
SC-11-V-143	3.00	2.36	0.52	1.24	4.00	98.84	7.08	1.56
SC-11-V-144	3.30	2.45	0.44	1.73	3.00	98.99	8.09	1.44
SC-11-V-146	1.00	2.42	0.41	2.11	2.00	99.35	2.42	0.41
SC-11-V-147	2.00	1.08	1.63	1.05	21.00	86.52	2.16	3.26
SC-11-V-148	1.50	1.85	1.27	5.54	8.00	87.80	2.77	1.90
SC-11-V-149	4.00	2.59	0.58	7.55	4.00	97.26	10.37	2.34
SC-11-V-150	5.00	2.58	0.63	8.15	2.00	98.48	12.91	3.13
SC-11-V-151	0.80	2.23	0.67	3.10	6.00	98.08	1.78	0.53
SC-11-V-152	0.00	-	-	-	-	-	-	-
SC-11-V-153	2.00	0.74	2.11	3.20	27.50	75.44	1.48	4.23
SC-11-V-154	1.40	-0.41	2.80	1.41	21.00	58.56	-0.57	3.92
SC-11-V-155	1.10	2.35	0.47	1.94	4.00	97.99	2.59	0.52
SC-11-V-156	2.10	2.26	0.49	1.58	3.00	97.99	4.75	1.02
SC-11-V-157	0.00	-	-	-	-	-	-	-
SC-11-V-158	0.00	-	-	-	-	-	-	-
SC-11-V-159	2.30	1.10	1.63	0.97	14.00	85.11	2.52	3.74
SC-11-V-161	1.40	0.56	1.94	1.01	38.00	78.62	0.78	2.72
SC-11-V-162	1.50	1.94	1.02	2.34	5.00	94.88	2.91	1.54

continued

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
SC-11-V-163	5.00	2.50	0.43	7.28	2.50	98.87	12.52	2.17
SC-11-V-164	4.30	2.42	0.49	7.44	4.60	97.95	10.39	2.10
SC-11-V-165	2.80	2.42	0.43	1.66	3.00	99.17	6.79	1.20
SC-11-V-166	3.00	2.01	0.89	1.47	9.00	95.78	6.02	2.66
SC-11-V-167	0.00	-	-	-	-	-	-	-
SC-11-V-169	3.10	2.25	0.47	1.28	2.00	99.55	6.96	1.45
SC-11-V-170	3.70	1.99	1.12	9.95	3.84	94.01	7.35	4.15
SC-11-V-171	0.00	-	-	-	-	-	-	-
SC-11-V-172	2.60	2.20	0.62	1.40	6.00	96.62	5.72	1.62
SC-11-V-173	0.00	-	-	-	-	-	-	-
SC-11-V-174	1.50	2.16	0.60	1.25	3.00	99.02	3.24	0.90
SC-11-V-175	4.80	1.99	0.99	6.83	3.92	88.01	9.55	4.75
SC-11-V-176	0.00	-	-	-	-	-	-	-
SC-11-V-177	0.00	-	-	-	-	-	-	-
SC-11-V-178	3.40	1.21	1.38	2.48	14.00	91.95	4.11	4.70
SC-11-V-179	1.00	-1.67	1.66	1.54	29.00	34.77	-1.67	1.66
SC-11-V-180	1.80	1.81	0.90	1.16	9.00	96.01	3.25	1.61
Totals	86.5	60.4	33.6	109.7	311.4	3093.9	165.8	80.8

Borrow Site J Composite Data

Mean (phi)	**1.92**
Std Dev (phi)	**0.93**
Weight % Fines passing #200	**4.04**
Visual % Shell	**7.91**
Weight % Pass #10	**92.67**

Table A-2- 11. Results from the 2003 and 2011 USACE borings within Borrow Site L.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-89	2.00	1.87	0.96	7.59	2.00	93.61	3.74	1.91
TI-03-V-90	0.50	0.79	1.28	1.50	19.00	85.07	0.40	0.64
TI-03-V-91	3.50	1.61	1.69	8.21	19.49	85.98	5.65	5.90
TI-03-V-93	2.30	2.15	0.83	8.78	15.00	95.40	4.94	1.90
TI-03-V-95	13.80	2.50	0.42	8.74	5.83	98.91	34.56	5.85
TI-03-V-96	3.20	1.30	1.40	3.11	11.94	90.33	4.16	4.47
TI-03-V-341	4.30	2.12	0.88	6.65	6.07	96.76	9.10	3.77
TI-03-V-342	2.00	1.89	1.04	3.92	15.00	91.58	3.77	2.07
TI-03-V-343	5.00	2.37	0.50	3.50	3.00	98.57	11.84	2.50
TI-03-V-344	2.30	0.81	2.23	1.71	22.22	79.18	1.86	5.13
TI-03-V-345	3.00	1.65	1.01	1.87	15.07	95.09	4.95	3.02
TI-03-V-346	3.00	1.93	1.09	7.90	13.00	91.73	5.78	3.26
TI-03-V-351	2.80	1.31	2.13	7.82	16.43	82.11	3.66	5.96
SC-11-V-68	6.00	2.41	0.52	8.51	4.00	97.81	14.47	3.11
SC-11-V-69	0.00	-	-	-	-	-	-	-
SC-11-V-70	1.90	2.16	0.66	1.96	4.00	98.01	4.11	1.26
SC-11-V-71	7.00	2.37	0.61	9.63	4.37	96.33	16.57	4.29
SC-11-V-72	9.00	2.53	0.45	10.41	3.00	98.89	22.80	4.09
SC-11-V-73	4.00	2.42	0.50	9.30	2.75	98.32	9.67	2.00
SC-11-V-74	1.400	2.05	0.53	1.36	2.00	99.08	2.87	0.74
SC-11-V-75	0.00	-	-	-	-	-	-	-
SC-11-V-76	1.00	2.03	0.72	1.62	5.00	95.50	2.03	0.72
SC-11-V-77	0.00	-	-	-	-	-	-	-
SC-11-V-78	5.40	1.67	1.38	6.60	14.43	91.24	9.02	7.44
SC-11-V-79	2.80	1.66	1.44	10.31	16.00	90.94	4.65	4.03
SC-11-V-80	0.50	0.99	2.09	7.90	18.00	80.55	0.50	1.04
SC-11-V-81	1.30	2.12	0.70	1.30	5.00	96.47	2.75	0.92
SC-11-V-82	0.80	1.84	1.23	8.43	3.00	92.28	1.47	0.99
SC-11-V-83	6.00	1.92	1.12	6.29	10.80	91.68	11.51	6.73
SC-11-V-84	0.60	0.14	2.02	1.37	30.00	76.77	0.08	1.21
SC-11-V-85	1.70	1.92	0.77	1.10	5.00	98.06	3.27	1.31
SC-11-V-86	4.40	1.40	1.69	6.95	16.82	87.12	6.14	7.42
SC-11-V-87	2.40	2.08	0.77	1.60	9.12	97.00	4.98	1.85
SC-11-V-88	2.00	2.37	0.62	4.87	5.70	98.09	4.74	1.25
SC-11-V-89	2.70	2.22	0.63	2.69	4.00	99.24	6.00	1.71
SC-11-V-90	2.60	-0.52	2.23	1.19	35.00	68.10	-1.35	5.79
SC-11-V-91	0.80	2.21	0.63	1.37	4.00	97.23	1.76	0.50

continued

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
SC-11-V-92	2.80	0.90	2.20	1.54	12.43	80.82	2.51	6.15
SC-11-V-93	2.20	1.94	0.72	1.49	5.00	97.25	4.28	1.58
SC-11-V-94	0.00	-	-	-	-	-	-	-
SC-11-V-95	7.90	1.46	1.66	1.49	12.52	87.48	11.51	13.11
SC-11-V-96	3.50	0.38	2.60	1.51	34.40	74.08	1.31	9.09
SC-11-V-97	2.10	1.64	1.26	1.87	12.00	91.77	3.44	2.65
SC-11-V-98	0.00	-	-	-	-	-	-	-
SC-11-V-99	0.00	-	-	-	-	-	-	-
SC-11-V-100	2.30	0.17	2.81	1.18	17.57	65.10	0.38	6.46
SC-11-V-101	0.00	-	-	-	-	-	-	-
SC-11-V-102	8.00	0.61	2.80	5.32	16.00	74.54	4.84	22.41
SC-11-V-103	5.20	1.52	1.42	1.39	10.62	87.12	7.92	7.40
SC-11-V-104	0.30	1.55	0.69	1.17	7.00	93.37	0.47	0.21
SC-11-V-105	0.00	-	-	-	-	-	-	-
SC-11-V-106	0.00	-	-	-	-	-	-	-
SC-11-V-107	6.00	0.11	3.11	3.49	38.20	66.57	0.67	18.66
SC-11-V-108	4.00	2.05	1.04	7.36	3.60	89.85	8.22	4.17
SC-11-V-109	0.00	-	-	-	-	-	-	-
SC-11-V-110	0.00	-	-	-	-	-	-	-
SC-11-V-111	7.70	2.13	1.05	6.68	14.12	87.32	16.42	8.06
SC-11-V-112	2.30	0.11	3.28	2.79	23.00	68.36	0.25	7.54
SC-11-V-113	2.60	0.30	2.71	1.20	8.00	72.30	0.77	7.04
SC-11-V-114	0.60	1.82	1.34	11.16	10.00	91.80	1.09	0.81
SC-11-V-115	2.80	1.35	1.94	10.14	16.00	84.33	3.79	5.42
SC-11-V-116	2.70	1.33	1.53	1.56	9.00	87.97	3.60	4.12
SC-11-V-117	0.00	-	-	-	-	-	-	-
SC-11-V-118	1.20	2.21	0.53	1.15	2.00	98.74	2.65	0.64
SC-11-V-119	2.00	0.13	2.48	1.20	19.00	70.72	0.27	4.95
SC-11-V-120	0.00	-	-	-	-	-	-	-
SC-11-V-121	6.60	2.56	0.48	7.73	3.12	98.54	16.86	3.17
SC-11-V-122	0.00	-	-	-	-	-	-	-
SC-11-V-123	0.90	0.16	2.55	1.28	28.00	70.67	0.14	2.30
SC-11-V-124	0.00	-	-	-	-	-	-	-
SC-11-V-125	2.00	0.93	1.35	1.17	4.00	86.25	1.86	2.70
SC-11-V-126	0.00	-	-	-	-	-	-	-
SC-11-V-129	0.00	-	-	-	-	-	-	-
SC-11-V-130	1.80	0.59	2.17	1.42	17.00	73.93	1.06	3.90
SC-11-V-131	2.40	1.85	0.89	1.30	3.00	96.06	4.44	2.12

continued

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
Totals	144.2	65.8	63.9	181.4	527.6	3943.6	226.8	203.1

Borrow Site L Composite Data

Mean (phi)	**1.57**
Std Dev (phi)	**1.41**
Weight % Fines passing #200	**5.03**
Visual % Shell	**11.80**
Weight % Pass #10	**87.90**

Table A-2- 12. Results from the 2003 and 2013 USACE borings within Borrow Site N.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
SC-13-V-01	7.4	2.19	0.53	2.43	10.86	96.36	16.22	3.93
SC-13-V-03	5.9	2.21	0.64	3.99	12.40	96.25	13.06	3.79
SC-13-V-14	6.1	2.24	0.57	3.55	9.41	95.18	13.68	3.50
SC-13-V-20	4.4	1.46	1.52	2.34	27.18	86.27	6.42	6.67
SC-13-V-21	7.3	2.42	0.53	4.13	5.48	97.73	17.65	3.84
SC-13-V-22	8.7	2.33	0.34	2.87	6.17	97.23	20.30	2.96
SC-13-V-24	8.4	2.37	0.44	1.65	8.81	94.38	19.95	3.72
SC-13-V-25	8.5	2.30	0.59	2.00	9.40	96.18	19.54	4.98
SC-13-V-26	5.7	2.19	0.52	3.40	4.83	99.32	12.46	2.94
SC-13-V-28	10.0	1.34	1.23	2.04	27.64	91.52	13.40	12.26
TI-03-V-65	4.8	2.37	0.43	0.00	7.25	98.67	11.36	2.08
TI-03-V-69	4.5	1.21	1.87	0.00	25.87	83.74	5.45	8.43
Totals	164.1	38.5	11.8	28.4	53.3	1632.2	380.9	108.1

Borrow Site N Composite Data

Mean (phi)	**2.07**
Std Dev (phi)	**0.72**
Weight % Fines passing #200	**2.44**
Visual % Shell	**12.65**
Weight % Pass #10	**94.77**

Table A-2- 13. Results from the 2003 and 2011 USACE borings within Borrow Site O.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-82	2.50	2.35	0.58	5.95	5.00	99.59	5.87	1.45
TI-03-V-83B	5.10	0.33	2.98	8.48	45.59	66.49	1.70	15.19
TI-03-V-85	9.10	2.18	0.75	9.54	4.56	93.51	19.82	6.81
TI-03-V-316	5.70	2.21	0.79	7.78	10.16	95.59	12.62	4.48
TI-03-V-322	6.10	2.58	0.43	5.66	3.00	99.34	15.72	2.63
TI-03-V-323	12.40	2.46	0.46	4.81	4.61	98.16	30.44	5.74
TI-03-V-324	7.00	1.85	1.22	6.16	8.80	86.92	12.98	8.57
TI-03-V-325	2.00	2.31	0.59	6.39	9.00	95.34	4.63	1.18
TI-03-V-326	12.70	2.54	0.43	7.83	1.16	99.77	32.21	5.47
TI-03-V-327	4.00	2.22	0.76	8.20	11.00	93.34	8.87	3.04
SC-11-V-22	20.10	2.52	0.43	6.32	1.00	99.76	50.64	8.61
SC-11-V-23	1.20	0.01	3.53	2.64	15.00	63.53	0.01	4.24
SC-11-V-24	1.70	0.13	2.85	1.23	22.00	64.14	0.22	4.84
SC-11-V-25	0.00	-	-	-	-	-	-	-
SC-11-V-26	0.00	-	-	-	-	-	-	-
SC-11-V-27	1.80	2.43	0.51	5.73	3.00	99.04	4.37	0.92
SC-11-V-28	3.00	2.49	0.45	7.70	2.00	99.32	7.46	1.36
SC-11-V-29	3.70	2.48	0.47	9.53	3.00	97.72	9.18	1.73
SC-11-V-30	2.70	2.74	0.66	13.30	4.00	98.35	7.41	1.77
SC-11-V-31	7.50	2.47	0.49	7.38	3.57	93.43	18.50	3.70
SC-11-V-32	7.50	2.52	0.43	8.90	1.00	99.66	18.91	3.19
SC-11-V-33	6.10	2.20	0.75	7.40	4.62	96.07	13.44	4.57
SC-11-V-34	6.70	2.39	0.47	5.77	1.40	99.42	16.03	3.16
SC-11-V-35	17.60	2.48	0.42	4.79	1.00	99.83	43.65	7.43
SC-11-V-36	3.50	2.45	0.45	7.18	3.69	96.39	8.58	1.59
SC-11-V-37	9.50	2.55	0.44	8.79	2.76	99.02	24.21	4.14
SC-11-V-38	3.30	2.41	0.46	5.18	4.00	97.43	7.96	1.51
SC-11-V-39	10.70	2.61	0.40	6.50	1.00	99.91	27.92	4.24
SC-11-V-40	6.00	2.53	0.41	8.09	1.00	99.77	15.16	2.45
SC-11-V-41	10.00	2.46	0.47	8.74	6.04	94.67	24.64	4.68
SC-11-V-42	16.00	2.53	0.44	9.44	1.38	96.52	40.46	7.09
SC-11-V-43	8.00	1.97	1.01	8.24	5.55	90.94	15.74	8.08
SC-11-V-44	8.70	0.74	2.56	1.72	18.62	77.77	6.42	22.26
SC-11-V-45	13.50	2.48	0.44	7.56	1.67	98.18	33.42	5.96
SC-11-V-46	7.50	2.31	0.52	6.14	1.31	97.86	17.34	3.89
SC-11-V-47	9.60	2.49	0.43	8.87	1.14	97.51	23.90	4.12
SC-11-V-48	0.00	-	-	-	-	-	-	-

continued								
Boring Number	**Thickness (ft)**	**Mean (phi)**	**Std Dev (phi)**	**Weight % Fines (passing #200)**	**Visual % Shell**	**Weight % Passing #10**	**Weighted Mean**	**Weighted Std Dev**
SC-11-V-49	0.00	-	-	-	-	-	-	-
SC-11-V-50	0.00	-	-	-	-	-	-	-
SC-11-V-51	1.50	0.41	2.56	1.24	10.00	73.61	0.62	3.84
SC-11-V-52	10.90	2.17	0.62	4.59	4.18	94.95	23.65	6.71
SC-11-V-53	0.00	-	-	-	-	-	-	-
SC-11-V-54	3.00	-0.03	2.81	6.94	1.00	68.89	-0.10	8.42
SC-11-V-55	0.00	-	-	-	-	-	-	-
SC-11-V-56	6.50	0.86	2.38	6.95	1.00	78.65	5.60	15.46
SC-11-V-57	2.30	2.03	0.56	2.72	2.00	96.48	4.66	1.28
SC-11-V-58	0.50	1.87	1.37	11.05	16.00	86.13	0.94	0.68
SC-11-V-59	7.40	2.27	0.68	9.54	2.62	96.58	16.77	5.05
SC-11-V-60	9.00	2.49	0.44	8.78	1.89	97.06	22.41	4.00
SC-11-V-61	0.40	1.84	1.09	2.06	14.00	86.96	0.74	0.44
SC-11-V-62	1.10	1.99	0.71	1.37	9.00	93.85	2.18	0.78
SC-11-V-63	0.00	-	-	-	-	-	-	-
SC-11-V-64	5.00	2.22	0.58	2.14	2.60	98.85	11.12	2.90
SC-11-V-65	6.00	2.40	0.53	2.35	4.33	96.67	14.38	3.17
SC-11-V-66	2.00	1.85	1.11	8.26	3.60	95.26	3.69	2.21
SC-11-V-67	6.10	1.36	1.67	2.42	11.51	85.51	8.27	10.18
Totals	247.6	76.1	36.6	237.6	193.5	3505.7	550.5	180.7

Borrow Site O Composite Data

Mean (phi)	**2.22**
Std Dev (phi)	**0.73**
Weight % Fines passing #200	**6.71**
Visual % Shell	**3.43**
Weight % Pass #10	**95.11**

Table A-2- 14. Results from the 2003 and 2011 USACE borings within Borrow Site P.

Boring Number	Thickness (ft)	Mean (phi)	Std Dev (phi)	Weight % Fines (passing #200)	Visual % Shell	Weight % Passing #10	Weighted Mean	Weighted Std Dev
TI-03-V-317	4.50	1.52	1.75	6.78	11.49	85.35	6.82	7.88
TI-03-V-320	14.00	2.42	0.44	6.18	4.77	93.56	33.90	6.17
SC-11-V-1	6.00	2.54	0.44	9.5	2.50	97.51	15.21	2.61
SC-11-V-2	5.00	2.42	0.54	7.41	1.00	99.34	12.10	2.70
SC-11-V-3	11.90	2.37	0.64	8.66	4.61	93.24	28.23	7.63
SC-11-V-4	17.80	2.57	0.47	11.00	2.85	98.05	45.73	8.38
SC-11-V-5	0.00	-	-	-	-	-	-	-
SC-11-V-6	6.50	2.67	0.54	13.19	2.00	99.14	17.33	3.48
SC-11-V-7	0.00	-	-	-	-	-	-	-
SC-11-V-8	8.00	2.39	0.52	8.64	2.10	99.09	19.16	4.20
SC-11-V-9	7.20	2.48	0.45	8.23	1.26	99.45	17.84	3.21
SC-11-V-10	10.80	2.48	0.47	8.12	1.93	98.62	26.79	5.07
SC-11-V-11	5.90	2.28	0.65	5.44	3.54	97.82	13.44	3.84
SC-11-V-12	0.00	-	-	-	-	-	-	-
SC-11-V-13	11.00	1.19	2.25	3.90	12.73	81.73	13.08	24.73
SC-11-V-14	13.00	2.51	0.42	8.78	1.00	99.44	32.58	5.50
SC-11-V-15	17.80	2.56	0.43	9.89	1.17	99.54	45.61	7.65
SC-11-V-16	0.00	-	-	-	-	-	-	-
SC-11-V-17	9.50	2.47	0.43	7.61	1.32	99.60	23.43	4.09
SC-11-V-18	12.00	2.48	0.43	10.43	1.00	98.96	29.76	5.13
SC-11-V-19	10.00	2.47	0.45	9.41	1.00	98.99	24.69	4.47
SC-11-V-20	6.00	2.41	0.45	8.79	1.00	97.49	14.46	2.68
SC-11-V-21	5.70	0.26	2.23	1.27	12.33	74.22	1.47	12.69
Totals	164.1	38.5	11.8	140.3	53.3	1632.2	380.9	108.1

Borrow Site P Composite Data

Mean (phi)	**2.32**
Std Dev (phi)	**0.66**
Weight % Fines passing #200	**8.60**
Visual % Shell	**2.99**
Weight % Pass #10	**96.45**

Addendum A-3: Geophysical Reports

Available Upon Request

Includes the following Hydrographic and Geophysical Survey Reports:

<u>2004 CHIRP Survey</u>

- Greenhorne and O'Mara, Inc., 2004. Final Report Marine Geophysical Investigation for the Evaluation of Sand Resource Areas Offshore Topsail Island, North Carolina, New Topsail Inlet to New River Inlet in Onslow Bay. OSI Report #03ES014-F, Prepared by Ocean Surveys, Inc for Greenhorne & O'Mara, Inc. and USACE Wilmington District.

<u>2006 & 2007 Hydrographic Bathymetry Survey</u>

- Greenhorne and O'Mara, Inc., 2006. High resolution remote sensing of potential hard bottom habitats: Topsail Island, NC. Project No. DACW54-02-D-0006. Sub-consultant Geodynamics.

- Greenhorne and O'Mara, Inc., 2007. High resolution 3D bathymetric Assessment of potential hard bottom habitats: Topsail Island, Surf City, and North Topsail Island, NC. Project No. DACW54-02-D-0006. Sub-consultant Geodynamics.

<u>2011-2012 Hydrographic, Multi-Beam Back Scatter, and CHIRP surveys</u>

- Geodynamics. 2012. High-resolution geophysical surveys of Borrow Areas G, H, J, L, O, and P Offshore Topsail Beach, North Carolina: November 2011-January 2012. Contract W912HN-10-D-0013. January 2012, Geodynamics.

- Geodynamics. 2013. Multibeam & Geophysical Surveys of Designated Borrow Areas (E, F, N, R, S) Topsail, North Carolina: September 2013. Contract W912HN-10-D-0013. February 2014, Geodynamics.

<u>2020 Hydrographic Bathymetry Survey</u>

- Geodynamics. 2020. Hydrographic surveys of Surf City/North Topsail Borrow Areas March 2020 Descriptive Report.

Addendum A-4: Geophysical Updates 2020

An additional bathymetric survey was conducted in March 2020 by Geodynamics using Multi-Bean Echosounder (MBES) for Borrow Areas G, H, L, N, O, and P. The purpose of this survey was to verify the existing conditions of the borrow areas and determine the magnitude of change using volume analysis with those surveys acquired from 2011-2013. A track line spacing of 400 feet was used in this survey and an interpolated surface was generated using Surfer 9 software. To reduce error and provide a more accurate depiction of volumetric change, the 2011-2013 data were re-gridded using the 2020 parameters. The finalized surfaces, at 5 feet resolution, were then exported to ArcGIS 10.5 and the Cut/Fill tool was used to obtain volumetric change. Geodynamics reported good agreement between years for all borrow areas with Borrow Area L exhibiting the largest mean difference at -0.25 feet and an estimated volumetric loss of 788,292 cubic yards. Although the 2020 survey reports minor changes of <0.3 feet, they also note that small changes over a large area can result in substantial volumetric change. USACE conducted a different volumetric change analysis over each borrow area. The 2020 bathymetric surveys were converted into individual raster files in order to compare volumetric change with the 2011/2013 surveys. The volumetric change was concentrated in the dredge boxes rather than the entire borrow area. For all borrow areas identified for the CSRM project there was a net loss of nearly 7 percent of borrow material. Despite this net loss, the total volume still meets the demand for the 50-year project. Table A-4-1 shows the estimated changes in bathymetry and volume for each borrow area. The method employed by Geodynamics resulted in a net volumetric change of 678,901 cubic yards while the USACE method resulted in a total volumetric loss of 284,704 cubic yards. Given the total 2020 survey volume of 20,677,212 cubic yards, these volumetric changes represent a volume reduction of 3.28 percent (Geodynamics) and 1.38 percent (USACE). Given the total volume of 35,776,143 cubic yards for all borrow areas selected for this project and an estimated project volume need of 32,300,000 cubic yards, this total volume loss is not expected to hinder project completion. Additionally, while USACE acknowledges that bathymetric changes and/or volumetric loss may require a review of dredge cut boxes, the reported volume losses should have no impact on the estimated initial construction volume of 2,000,000 cubic yards.

Table A-4- 1. Bathymetric update and analysis results for Borrow Areas G, H, L, N, O, P.

Borrow Area	2020 Mean Difference (feet)	2020 Cut/Fill Vol. Loss (cubic yards)	2020 Cut/Fill Vol. Gain (cubic yards)	2020 USACE Range of Differences (feet)	2020 USACE Vol. Change (cubic yards)	Estimated Borrow Area Volume (cubic	% Change Based on Estimated Volume Loss from USACE

						yards)	
G	-0.11	134,406	22,028	-1.46 to +1.65	23	2,642,798	0.0009
H	-0.07	23,005	5,582	-0.99 to +0.74	-11,830	1,428,988	-0.8279
L	-0.25	788,292	105,749	-2.61 to +1.71	-317,150	3,616,546	-8.7694
N	0.39	6,376	670,951	-1.46 to +1.54	151,756	2,539,483	5.9759
O	-0.14	491,628	101,044	-3.06 to +2.04	-18,970	7,053,742	-0.2689
P	-0.19	173,057	32,509	-1.71 to +1.37	-88,533	3,395,655	-2.6072
Total Vol. Change		**1,616,764**	**-937,863**		**-284,704**		**-6.4967**
Net Vol. Change		**678,901**					

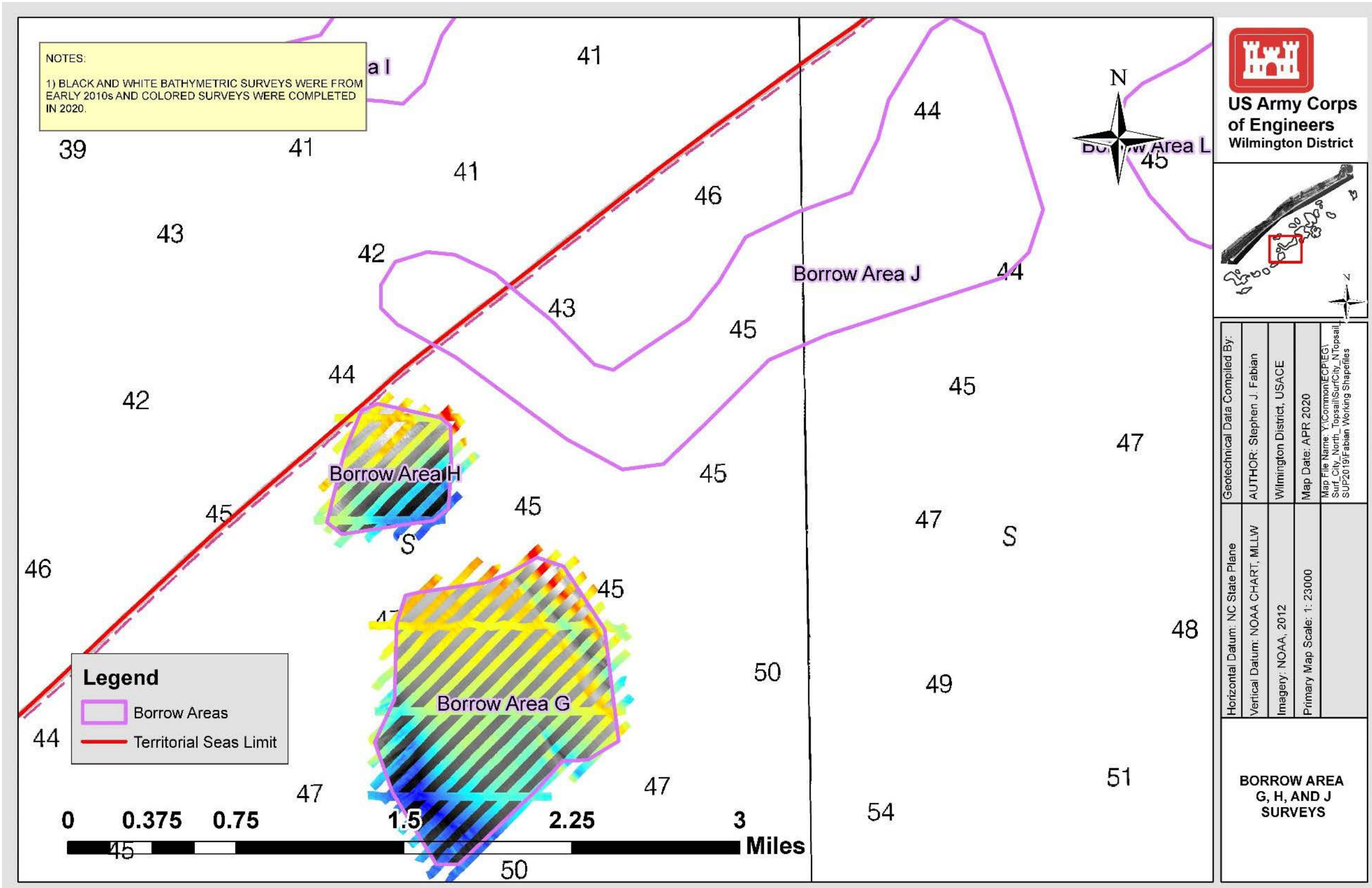

Figure A-4- 1. Bathymetry comparison results for Borrow Areas G and H conducted by USACE in 2020.

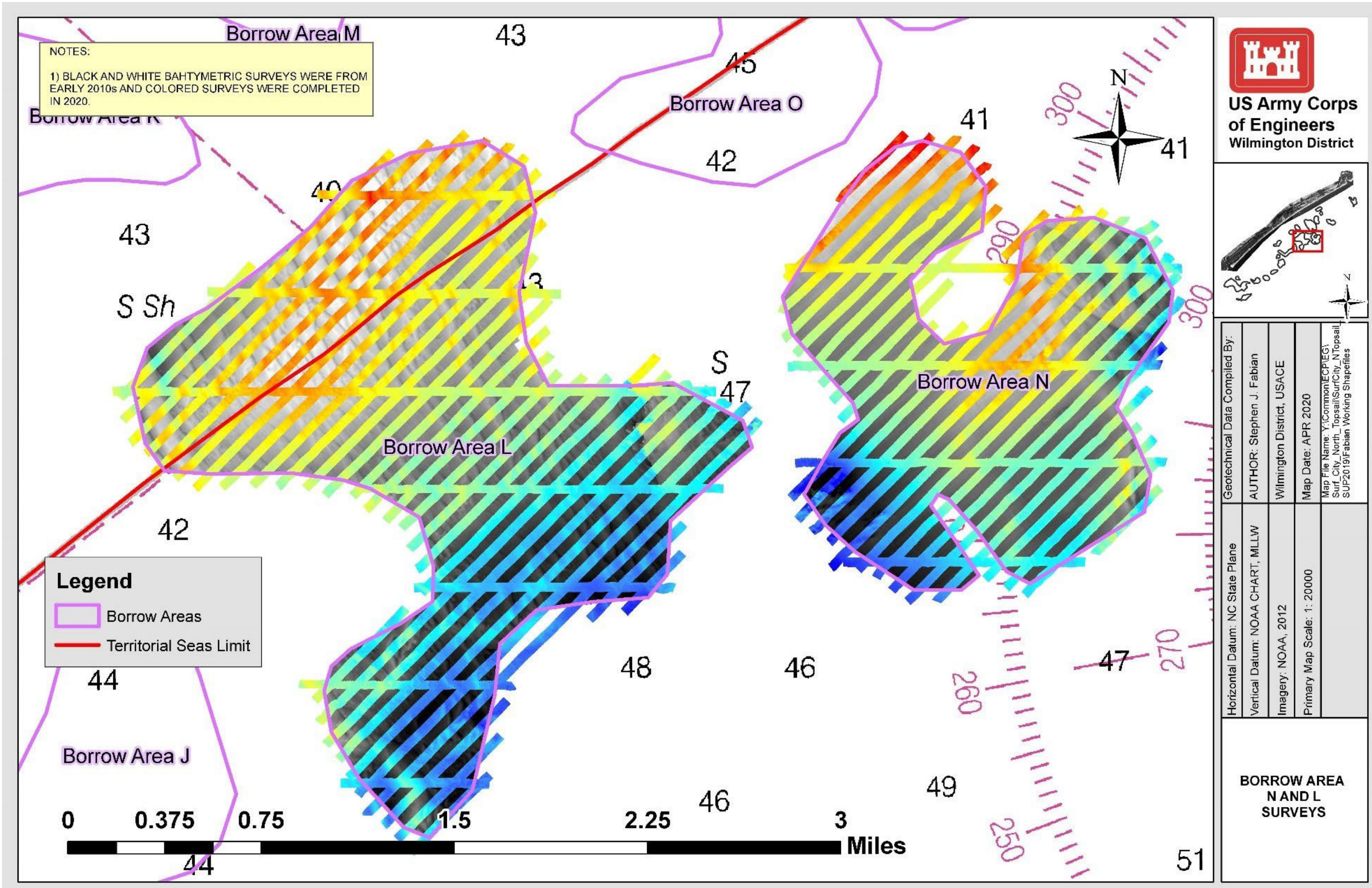

Figure A-4- 2. Bathymetry comparison results for Borrow Areas L and N conducted by USACE in 2020.

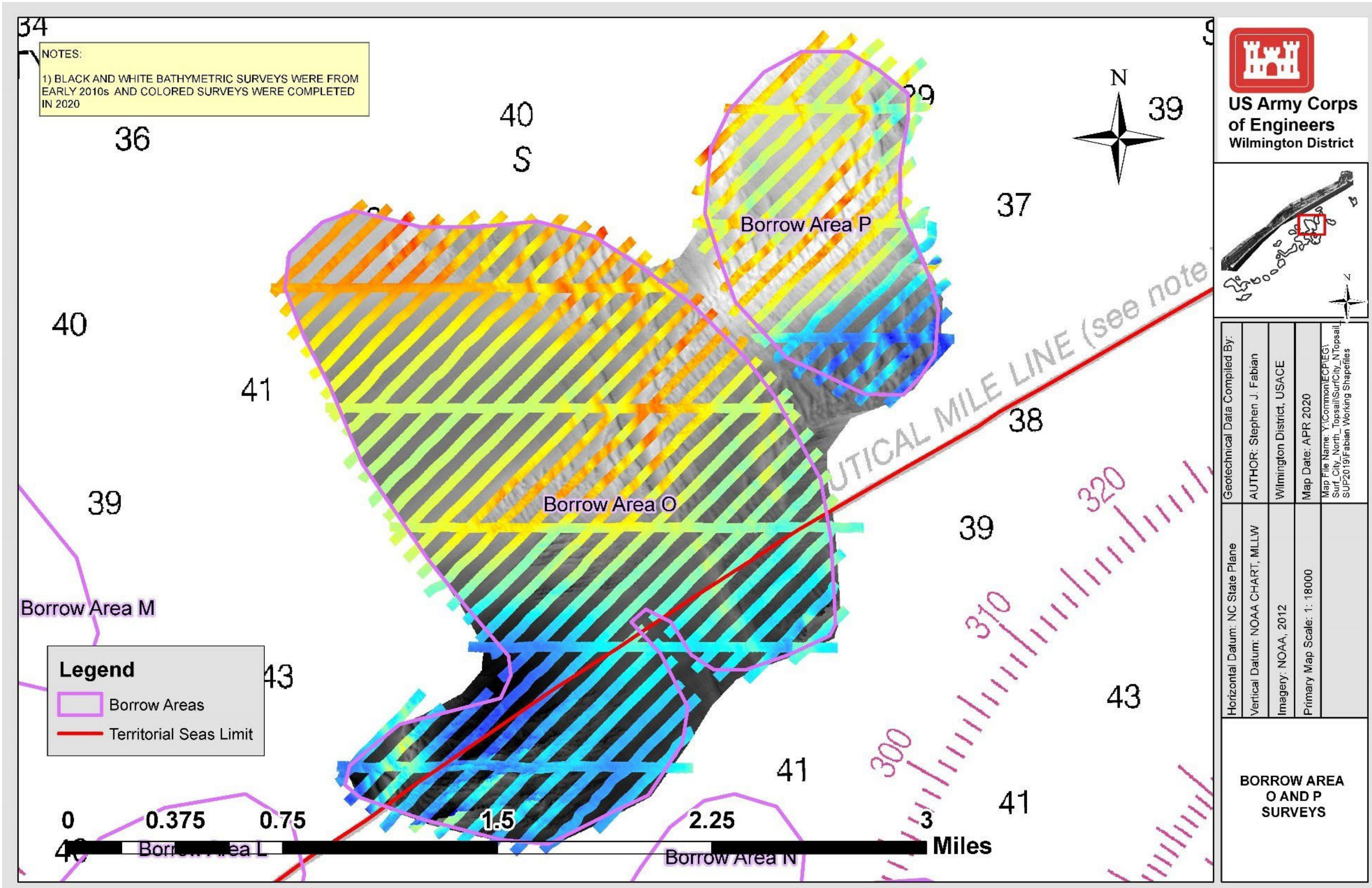

Figure A-4- 3. Bathymetry comparison results for Borrow Areas O and P conducted by USACE in 2020.

Addendum A-5: Project and Analysis Updates 2021-2024

In 2020, work began to complete the construction phase of the Surf City and North Topsail Beach CSRM project using Disaster Relief Act of 2019 (DRA 2019) construction funding. In 2021, North Topsail Beach opted out of the Federal project and chose not to sign the Project Partnership Agreement (PPA) leaving Surf City as the sole sponsor of the federal project. Because of the funding constraints associated with DRA 2019 funding, specifically the requirement to construct the entire authorized project, a General Reevaluation Review (GRR) was determined necessary to use the funds to construct the Surf City portion as a standalone element. This resulted in the creation of the Surf City CSRM GRR which includes all the previously investigated borrow areas for the Surf City and North Topsail Beach CSRM project and the West Onslow Beach Coastal Storm Damage Reduction (CSDR) project.

During this time, Borrow Areas G, H, J, L, N, O, and P as well as Borrow Area A from the former West Onslow Beach Coastal Storm Damage Reduction project were reevaluated and the District developed High Confidence Volumes for those areas within and beyond 3 nautical miles (territorial sea limit). These volumes do not represent the total amount of available material, but instead represent the estimated volume of material that could be taken from the borrow area with a high degree of confidence in both the quality and quantity of material. These volumes were established by raising the original dredge cut depths from the 2020 Geotechnical Appendix to an elevation that avoids all instances of cemented sand, rock fragments, and cemented gravel found in the field descriptions of the boring logs. Note: dredge box delineations and/or volumes are subject to change and should only be regarded as drafts that are currently under development (Figure 1-Figure 4).

The High Confidence Volumes for Borrow Areas A, G, H, J, L, N, O, and P were compiled (Table 1) and includes a total of approximately 20.5 million cubic yards with approximately 14.7 million cubic yards within 3 nautical miles (territorial sea limit) and approximately 5.8 million cubic yards beyond 3 nautical miles (territorial sea limit). The total estimated volume of material for these borrow areas is approximately 20.5 million cubic yards. While this interpretation represents a reduction in overall borrow material, it was not expected to impact the life of the project and additional geotechnical investigations are ongoing to further delineate beach quality material suitable for placement at Surf City.

Table 1. High Confidence Volumes for Borrows A, G, H, J, L, N, O, and P.

Borrow Area	Estimated Volume (cubic yards)	High Confidence (HC) Volume (cubic yards)	HC Within 3 NM (cubic yards)	HC Beyond 3 NM (cubic yards)
A	13,457,335	10,637,111	9,542,668	1,094,443
G	2,642,798	1,106,347	0	1,106,347
H	1,428,988	268,230	0	268,230
J	1,641,596	372,319	46,485	325,834
L	3,616,546	1,423,031	587,305	835,727
N	2,539,483	1,595,167	0	1,595,167
O	7,053,742	3,498,525	2,926,335	572,190
P	3,395,655	1,589,265	1,589,265	0
Totals	**35,776,143**	**20,489,997**	**14,692,058**	**5,797,939**

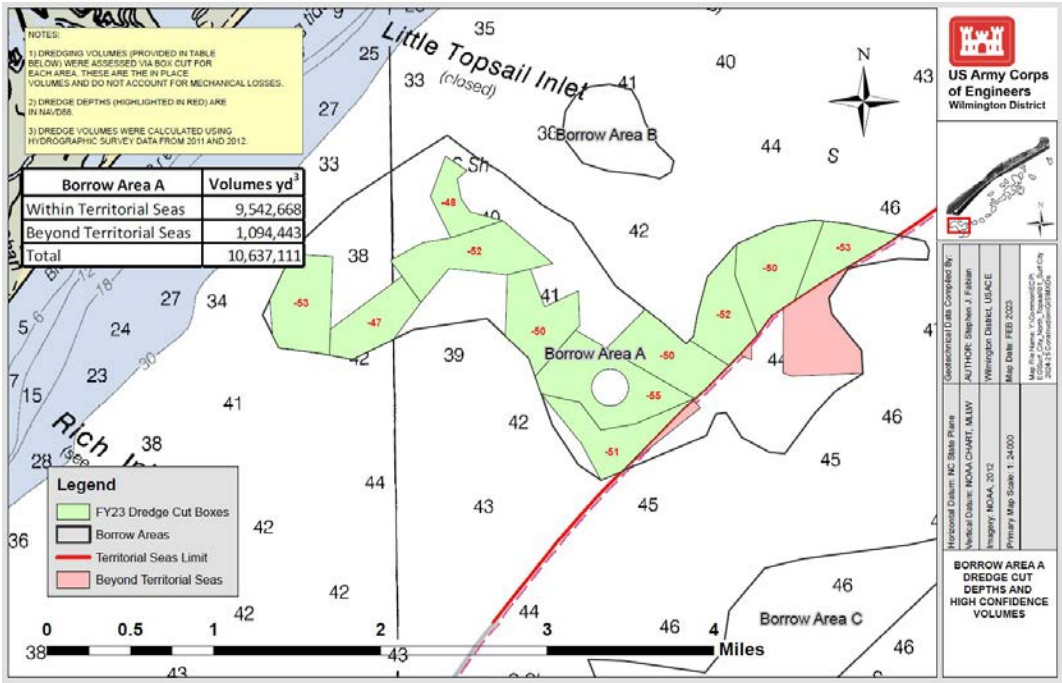

Figure 1. High Confidence Volumes for Borrow Area A offshore Surf City, NC. (Dredge box delineations and/or volumes are subject to change and should only be regarded as drafts that are currently under development.)

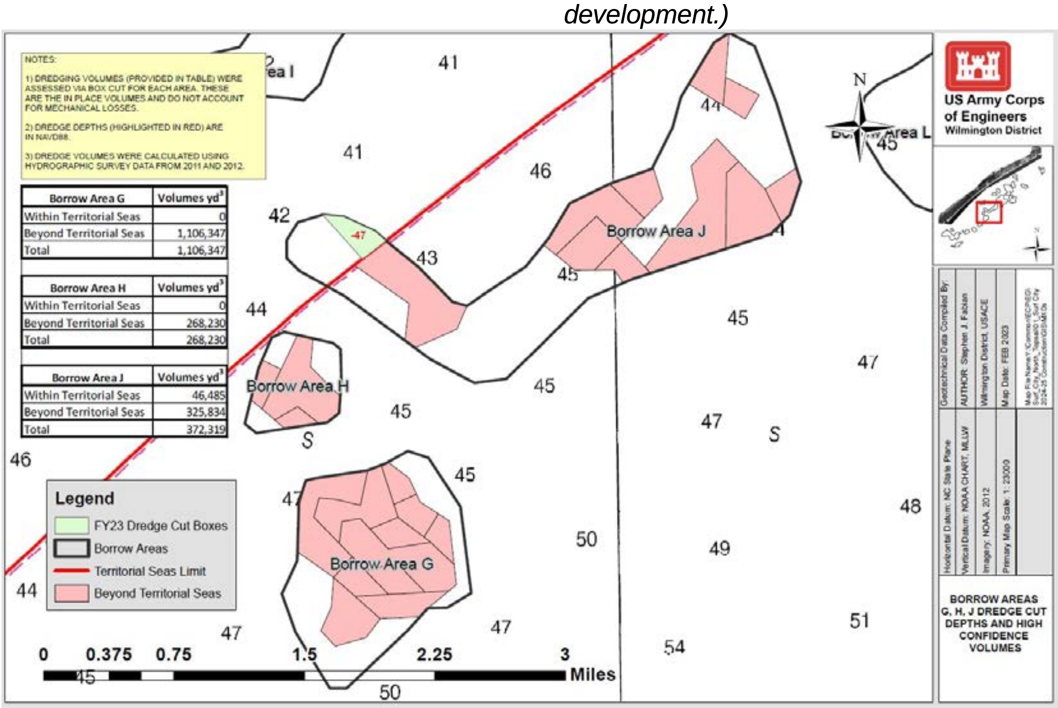

Figure 2. High Confidence Volumes for Borrow Areas G, H, and J offshore Surf City, NC. (Dredge box delineations and/or volumes are subject to change and should only be regarded as drafts that are currently under development.)

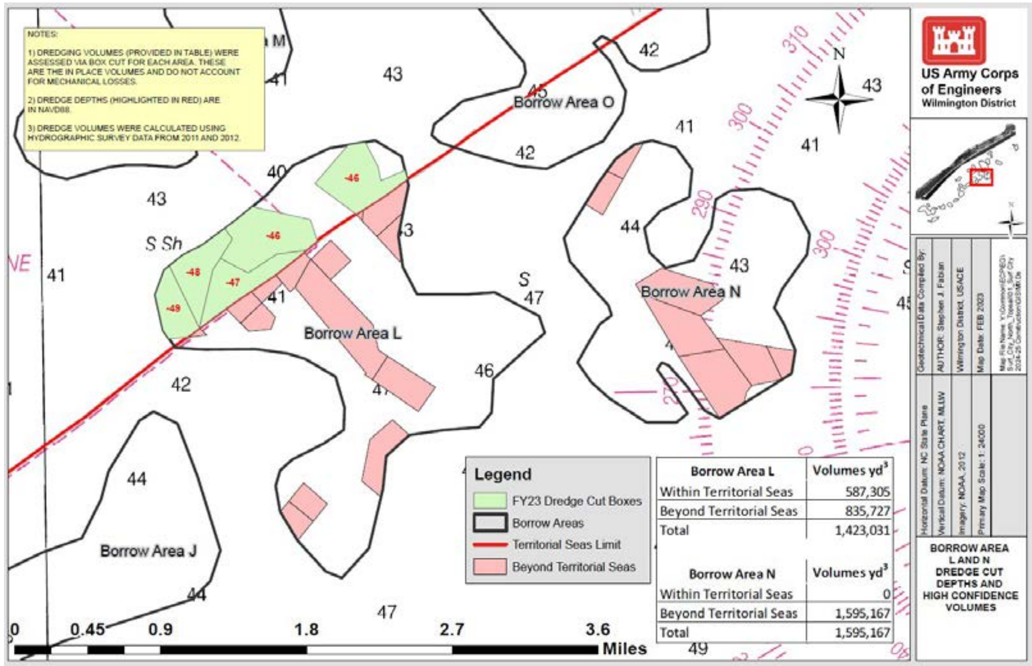

Figure 3. High Confidence Volumes for Borrow Areas L and N offshore Surf City, NC. (Dredge box delineations and/or volumes are subject to change and should only be regarded as drafts that are currently under development.)

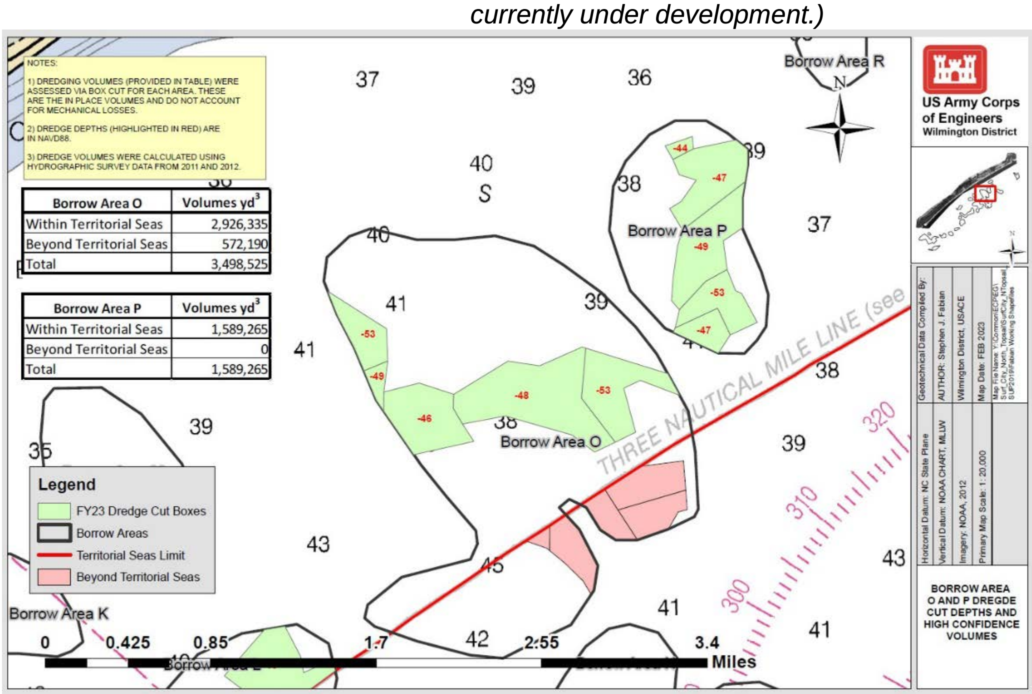

Figure 4. High Confidence Volumes for Borrow Areas O and P offshore Surf City, NC. (Dredge box delineations and/or volumes are subject to change and should only be regarded as drafts that are currently under development.)

Addendum A-6: Feasibility Study Supplemental Data

Supplemental data and analysis developed during the Surf City and North Topsail Beach Feasibility study is included here. This included preliminary geotechnical analysis and sediment compatibility for Borrow Areas A-T.

Appendix C: Geotechnical Analyses (2010)

1. Regional Geology

Physiography and Geomorphology. The study area encompasses Topsail Island and nearshore Onslow Bay. Topsail Island is a 40 kilometer long barrier island, which lies within the Atlantic Coastal Plain Physiographic Province. It is bounded by New River Inlet to the northeast, New Topsail Inlet to the southwest, Onslow Bay to the southeast, and the Atlantic Intracoastal Waterway (AIWW) to the northwest. Onslow Bay is a modern embayment of the Atlantic Ocean. It is bounded by Cape Lookout to the north and Cape Fear to the south. Present on Topsail Island are beaches, dunes, and marshes, landforms typical of barrier island complexes. On the nearshore floor of Onslow Bay are submarine scarps, shoals, and bars.

Stratigraphy. The Atlantic Coastal Plain and the inner continental shelf of Onslow Bay are both underlain by relatively flat-lying sedimentary units which gently dip and thicken to the southeast. This large sedimentary wedge includes both sediments which have not been indurated or cemented and rock units. The oldest (lowest units) were deposited during the Cretaceous Period, from 144 to 65 million years ago. The youngest part of the wedge dates to the Quaternary Period, from 1.8 million years ago to 10,000 years ago. This sediment and sedimentary rock wedge overlies pre-Mesozoic (older than 248 million years ago) crystalline basement rock (Horton and Zullo, 1991). A patchy veneer of Holocene (10,000 years ago to present) sand and gravel overlies the Quaternary strata in the project area.

Coastal Processes. Dynamic coastal processes continually shape the barrier islands of southeastern North Carolina. Rivers and streams entering Onslow Bay are generally small with low gradients. Their continentally derived sediment loads are therefore not very large. In addition, much of this fluvial sediment becomes trapped within the river estuaries. This lack of significant sediment discharge into Onslow Bay limits the build-up of nearshore continental shelf sand deposits. In other areas along the Atlantic coast these nearshore deposits are an important source of sand. When deprived of this source of sand as at Topsail Island, seasonal storms and longshore currents can cause episodic severe shoreface erosion and migration (Cleary, 1968; Sarle, 1977; Riggs and others, 1996; Cleary 2002).

2. Site Geology

Topsail Island. Several Oligocene formations outcrop on the nearshore floor of Onslow Bay. These strata extend westward under Topsail Island, vertically removed from the island surface. The stratigraphy and lithology of these strata are described below in paragraph "Onslow Bay." The geologic materials of concern to the project on Topsail Island are the surficial sand soils.
Sand soils encountered on the Topsail Island beaches are classified as fine- to medium-grained poorly graded sands according to the Unified Soils Classification System. These sands are the result of a complex combination of factors. Part of the sand is accumulated from storm overwash and longshore drift. Another part results from the biological, chemical, and physical erosion of nearshore sedimentary rocks. Winnowing by wind and wave action results in the predominantly fine- to medium-grained poorly-graded sands on the beach today.

Onslow Bay. The continental shelf in Onslow Bay is composed of a complex sequence of seaward dipping Tertiary age (65 million to 1.8 million years ago) strata, which was deposited during an age of periodic sea-level fluctuations (Hine and Riggs, 1986; Snyder and others, 1985, 1986; Snyder and others, 1991). The oldest rocks outcropping within the study area are Oligocene age (33.7 million to 23.8 million years ago) limestones submerged offshore of Topsail Island (USACE, 2010; Greenhorne & O'Mara (OSI), 2004). Riggs and others (1985) describe these limestones as the Belgrade and Trent formations, which consist of "moldic biomicrudite (Folk, 1974) limestones with interbedded calcarenite sands and grayish-green calcareous quartz sands." A stratigraphically similar unit named the River Bend Formation, which consists of olive green quartz sand and silt, is reported to also underlie areas offshore of Topsail Island (OSI, 2004). Northeast and east of the survey area lies a major unconformity separating the Oligocene rock and sediments from the younger Miocene (23.8 million to 5.3 million years ago) Pungo River Formation.

Quaternary paleofluvial channels, which generally trend normal to shore, crosscut the older strata offshore of Topsail Island. These channels were down cut during a period of lower sea level elevation. The paleofluvial channels are remnant streambeds, which were infilled with sediments during Pliocene to Pleistocene times (1.8 million years ago to 10,000 years ago) (Hoffman, C. W. and others, 1994), and were drowned during the Holocene sea-level rise (Belknap, 1982; Hine and Snyder, 1985, Snyder and Snyder, 1992).

Surficial Holocene sedimentary deposits are scarce offshore of Topsail Island in Onslow Bay. Much of the native beach sand is derived from the physical and biological erosion of Oligocene rock and strata submerged in Onslow Bay. These sediments are then reworked, redistributed and deposited within submarine valleys and ridges, or along the shoreface of Topsail Island (Cleary, 1968; HDR, 2002; HDR, 2003; Meisburger, 1979; McQuarrie, 1998; Riggs and others, 1996; Snyder and Snyder, 1992).

3. Subsurface Investigation

Historical Data Information in the offshore areas of Topsail has not been studied or documented in the past. HDR Engineering Inc. of the Carolinas (HDR) was hired in fall of 2002 to gather information about the area and to make recommendations of where the most promising areas are for borrow material for the Topsail Beach Coastal Storm Damage Reduction Project. HDR hired Dr. William Cleary of the University of North Carolina at Wilmington as a consultant to assist in the assessment. The area offshore of Topsail Island is one of the areas of interest for Dr. Cleary. The study included mapping (side scan sonar) and classifying the seafloor composition by collecting physical samples of the bottom. This information was used to locate areas with the most promise for use as borrow for beachfill. HDR along with Dr. Cleary submitted a report in March of 2003 outlining the recommended areas offshore of Topsail Beach for use as potential borrow sites. This report was titled "Assessment of the Availability of Beachfill Quality Sand Offshore Topsail Island, Topsail Beach, Pender County, North Carolina". The recommended offshore areas were the focus of the subsequent geophysical investigation.

Geophysical Investigation

a. General. A search for suitable beach fill materials for this project was begun offshore in Onslow Bay. A marine geophysical investigation was conducted by Ocean Surveys March 27 to April 17, 2004, in order to locate and evaluate potential sand resource areas. Approximately 315 miles of bathymetric and sub-bottom data were collected along 60 tracklines. Twenty-two (22) tracklines were shore-parallel and twenty-eight (28) tracklines were run perpendicular to shore along with 10 diagonal tie lines to insure thorough coverage.

b. Sand Borrow Search Area. Geophysical data was collected in the area between 0.5 nautical miles (30 foot isobath) to 5.0 nautical miles offshore of Topsail Island. The site stretches nearly 23 nautical miles from Rich Inlet to northeast of New River Inlet. Survey limits were established to further resolve sand resource areas identified by earlier surveys.

c. Geophysical Methods. Two types of sub-bottom methods were used: a “CHIRP Sonar” seismic reflection profiler, which generates a high frequency, short duration acoustic pulse providing high resolution of shallow sub-bottom strata; and a “Boomer” seismic reflection profiler which uses a low frequency pulse to achieve deeper penetration of the sub-bottom strata. These were run simultaneously to achieve the best possible resolution and penetration. Augmenting the seismic equipment was survey equipment that allowed real-time depth sounding, positioning, and motion (heave) corrections.

d. Positioning System. A differential global positioning system was used to determine position along the seismic lines. Equipment included a Trimble 4000 Global positioning System (GPS) and a Leica MX52R U.S. Coast Guard (USCG) Differential Beacon Receiver interfaced with HYPACK software. Navigation fixes were recorded on an onboard PC every second with an accuracy of better than 3 feet.

e. Depth Sounder. Bathymetric data was collected at a near continuous rate using an Innerspace Model 448 Digital Depth sounder, which operated at a frequency of 200 kHz. Tidal data from the NOAA station in Beaufort, North Carolina were used for tidal corrections.

f. <u>CHIRP Sonar System</u>. The Contractor accomplished the high-resolution sub-bottom profiling utilizing an EdgeTech Xstar Full Spectrum "CHIRP" Sub-bottom Profiler system operating with frequencies of 0.5-12 kilohertz. The system has three components: a deck unit that is comprised of a PC system and amplifier, an underwater cable, and a Model 512 towed vehicle that houses the transducers. The tow fish vehicle emits a high frequency FM pulse over the full spectrum range of 0.5-12 kilohertz for a 20 millisecond period, and the acoustic return is received by a hydrophone array, which allows high resolution of the shallow subsurface. The higher frequency yields higher resolution with a tradeoff in lesser depth penetration.

g. <u>Seismic Reflection Profiling System</u>. Deeper sub-bottom penetration was accomplished using an Applied Acoustics 100-300 joule "boomer" system comprised of a boomer plate, power supply, hydrophone array, TSS-model 360 filter and time-varied-gain system, and an EPC 1086 thermal paper recorder. The "boomer" employs a sound source that utilizes electrical energy discharged from a capacitor bank to rapidly move a metal plate in the transducer bed. The short duration motion of the metal plate creates a broad-band (500-8000 hertz) pressure wave capable of penetrating hundreds of feet of marine sediments under favorable site conditions.

h. <u>Summary of Geophysical Results</u>

<u>Stratigraphy.</u> The geophysical and bathymetric surveys showed that shallow rock scarps and outcrops dominate and control the submarine topography offshore of Topsail Island. A surficial sand horizon was resolved. However, it is very discontinuous and broken by Oligocene rock outcrops. Erosion and reworking of this rock contributes coarse and fine-grained materials to the surficial sand.

This decreases its aesthetic value as beach fill. The thickest sequence of unconsolidated sediment occurs in or adjacent to the paleochannels. These sediments tend to be dominated by estuarine muds and fine sands and thus unsuitable as beach fill. Borrow areas are generally be configured to avoid these channels.

<u>Vibracore Targets.</u> The subsurface investigation was performed between May and November 2003. The boring

locations were based on the seismic data available from the geophysical investigation conducted by Greenhorne & O'Mara (OSI).

Borrow Areas. The results of the 2004 geophysical survey in combination with vibracore data were used to identify potential borrow areas within the study area.

Vibracore Investigation

a. Field Investigation. The subsurface investigation was performed between May and November 2003. The criteria for the boring locations were between 1 and 6.5 miles from the beach, water depth greater than 30 feet, and change in seismic profile, which could represent differing soil types. A total of 369 borings were performed in the Topsail Island area, 167 of which were for the Topsail Beach project. Borings performed for the Topsail Beach project are designated TI-V-1 through TI-V-12A, TI-V-105 through TI-V-153A, TI-V-170 through TI-V-192, TI-V-194 through TI-V-246, TI-V-263, and TI-V-363 through TI-V-365 (Greenhorne & O'Mara (OSI), 2004). Other borings from TI-V-1 through TI-V-369 not mentioned here were performed for the Surf City/North Topsail Beach project. Borings were performed offshore of Topsail Beach, in the Banks Channel behind Topsail Beach, in the connecting channel between the Atlantic Intracoastal Water Way (AIWW) and New Topsail Inlet, and in New Topsail Inlet.

Borings were performed from the USACE Snagboat *SNELL* using a 3 7/8 inch diameter, 20-foot long, Alpine vibracore drill machine. The sampler consists of a metal barrel in which a plastic cylinder or tube is inserted. After the plastic tube was inserted, a metal shoe was screwed onto the plastic tube and then the metal barrel. The shoe provided a cutting edge for the sampler and retained the plastic tube. An air-powered vibrator was mounted at the upper-most end of the vibracore barrel, and the vibrator and the vibracore barrel was mounted to a stand. This stand was lowered to the ocean floor by the Snell's crane, the vibrator was activated and vibrated the vibracore barrel into the ocean sediment. The sediment sample is retained in the plastic tube. All borings were drilled to a depth of 20 feet below the ocean floor, unless vibracore refusal was encountered. Vibracore refusal was defined as a penetration rate of less than 0.1 feet in 10 seconds.

b. Laboratory Analysis. The recovered vibracore tubes were visually classified by Wilmington District personnel in accordance with the Unified Soils Classification System (USCS). Samples were taken at a minimum of every two feet or at each change of material. A total of 1327 samples were collected in the Topsail Island area, of which 595 samples were tested for this project. Grain size tests were performed in accordance with ASTM D-422 using a fourteen-sieve test and visual classifications were performed in accordance with ASTM D-2488, by Wolf Technologies, Inc. The sieves used in these tests were the 3/4, 3/8, Number 4, Number 7, Number 10, Number 14, Number 18, Number 25, Number 35, Number 45, Number 60, Number 80, Number 120, and Number 230. Boring logs and laboratory analysis can be found in the Surf City and North Topsail Beach Coastal Storm Damage Reduction Project 2010 Final Integrated Environmental Impact Statement Appendix C Attachments (USACE, 2010).

4. Compatibility Analysis

The compatibility analysis compares the grain size of the “native beach” or the “reference beach” with the material in the proposed borrow material. The procedure for calculating the overfill ratio for borrow areas in relation to the reference beach was performed in accordance with the U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory Automated Coastal Engineering System (ACES) software version 4.01. This procedure is discussed in section V-4-1.e(3)(i) of the U.S. Army Corps of Engineers Engineer Manual (EM) 1110- 2-1100, part V, dated 1 August 2008, titled Coastal Engineering Manual. As stated in this manual, the overfill ratio is the primary indicator of the compatibility of the borrow material to the beach material, with a value of 1.00 to 1.05 considered optimum for sediment compatibility. Obtaining this level of compatibility is not always possible due to limitations in available borrow sites and an overfill ratio of 1.5 is generally considered acceptable.

5. Archeological Resources Survey

Mid-Atlantic Technology and Environmental Research, Inc. (MATER) conducted magnetometer and side-scan sonar (acoustic) surveys to identify archeological resources that may be present in the preliminary borrow areas from the fall 2004 to spring 2005. The side-scan sonar survey was used to further delineate hard bottom identified in the borrow areas in the geophysical investigation. Line spacing for this survey was approximately 65 feet and the survey covered an area of approximately 14.1 square nautical miles. Hard bottom consisting of high, moderate, and low relief based on the elevation changes were identified in several of the preliminary borrow areas. As a result, three preliminary borrow areas (I, K, and M) were eliminated from further consideration as borrow sources.

6. Hard Bottom Resource Confirmation and Characterization Study

Anamar Environmental Consulting, Inc. conducted in-situ diver ground truthing of several borrow areas in the spring 2008. Twelve transects were conducted to confirm and characterize hard bottom at five borrow areas (G, J, L, O, and T). Transects were planned for locations where hard bottom was identified by MATER in the archeological resources survey. Hard bottom of low and moderate relief were identified for all of the transects with the exception of one transect in borrow area J (J1), where no hard bottom was identified. Concurrently, applicability of the North Carolina hard bottom buffer rule (NCAC 07H. 0208(b)(12)(A(iv)), which identifies a 500 meter buffer for dredging operations around high relief hard bottom had been discussed for the coastal storm damage reduction projects potentially impacting hard bottom. In August 2008, State and Federal resource agencies concurred with a USACE, Wilmington District proposal to establish a hard bottom buffer consisting of 500 meters (1,640 feet) for high and moderate relief hard bottom and 122 meters (400 feet) for low relief bottom.

7. Sand Borrow Areas

After completion of the archeological resources survey, eleven offshore borrow areas were identified for the Surf City/North Topsail Beach project and are labeled as G, H, J, L, N, O, P, Q, R, S, and T (USACE, 2010). The material classification ranged from clean sand (SP), slightly silty sand (SP- SM), with minor amounts of silty sand (SM), silt (MH and ML), and clay (CH) (USACE, 2010). The boundaries of the borrow areas have been limited to preclude material with classification of silty sand, silt, and clay by adjusting the depth of the borrow area at vibracore locations.

The State of North Carolina implemented new rules in 2007 governing sediment compatibility for beach nourishment. The rules are titled “Technical Standards for Beach Fill Projects” and are found in 15A North

Carolina Administrative Code (NCAC) 07H.0312. The standards require compatibility of the native beach with borrow sources in regards to the percentage of silt, granular sediment, gravel, and calcium carbonate (or shell content for existing projects). Borrow Area R was subsequently eliminated due to elevated silt concentration. Based on the results of the compatibility analysis, the total estimated volume in the remaining ten borrow areas is approximately 27.59 million cubic yards. This amount of material is insufficient to meet the required volume for the NED plan of 32.3 million cubic yards.

Therefore, borrow areas identified for the Topsail Beach Federal coastal storm damage reduction project were considered. By evaluating the borrow areas for all Topsail Island coastal storm damage reduction projects, sufficient material is available for the two Federal and two non-Federal projects. The six borrow areas identified for the Topsail Beach Federal coastal storm damage reduction project (A, B, C, D, E, and F) have been included with the aforementioned ten borrow areas for the Surf City/North Topsail Beach project. By evaluating all Topsail Island offshore borrow areas together, the sixteen borrow areas contain approximately 50.4 million cubic yards of borrow material. The two Federal and two non-Federal coastal storm damage reduction projects currently planning to use material from these borrow areas have volume requirements of approximately 46.3 million cubic yards or about 92 percent of the available borrow material in all of the borrow areas evaluated for the Federal projects.

All of the remaining borrow areas comply with the beach fill standards with the exception of borrow areas A F, L, S and P. Borrow areas A and L exceed the silt standard by 0.4 and 0.1 percent respectively. Borrow areas F and S exceed the granular sediment standard by 0.9 and 0.5 percent respectively. Borrow area F and P exceed the gravel standard by 3 and 1.1 percent respectively.

The borrow areas in which the standards were exceeded for the various characteristic (A, F, L, S, and P) have been retained as all borrow areas will be further characterized during the plans and specification phase of this project. Additional borings will be performed to comply with the NC beach fill standard of 1 core/acre or 1,000 feet spacing. The characteristics of the remaining ten borrow areas is shown in Table C-1. As shown in this table, the borrow areas are typically between 1 and 6 miles offshore and have pre-dredge bottom depths of 50 feet or less.

8. Conclusion

An extensive investigation was conducted for borrow sources for the Surf City/North Topsail Beach Federal coastal storm damage reduction project which included seismic and sonar studies, subsurface investigation using numerous vibracores, an archeological resources survey, and a hard bottom confirmation and characterization study. The number and configuration of borrow areas for the project has been continuously modified throughout the process to incorporate the additional data.

The borrow areas were re-evaluated after the North Carolina beach fill standards were implemented in 2007. At that time ten borrow areas were identified for the project. However, the volume of material in these borrow areas is insufficient to meet the project requirements. Therefore, borrow areas identified for the Topsail Beach Federal coastal storm damage reduction project were considered. By evaluating the borrow areas for all Topsail Island coastal storm damage reduction projects, sufficient material is available for the two Federal and one non-Federal projects.

Currently sixteen borrow areas have been identified for the Surf City/North Topsail Beach Federal coastal storm damage reduction project. Five of these borrow areas (A, F, L, P, and S) exceed the NC beach fill standards slightly for various characteristics. Because all borrow areas will be evaluated further during the plans and specifications phase of this project, these borrow areas have been retained. Additional vibracores will be performed in all borrow areas to comply with the NC beach fill standards of 1 core/acre or 1,000 feet spacing.

9. References

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Table C-1
Borrow Area Characteristics

Borrow Area	Mean Grain Size	Estimated Volume (Million Cubic Yards)	Distance offshore (Miles)	Pre-Dredge Surface/Bottom Elevation (feet MLLW)
A	2.36 phi (0.20 mm)	13.2	1 to 3	-38.5 to –49.0
B	2.17 phi (0.22 mm)	0.82	1.5 to 2.5	-42.2 to –43.2
C	2.32 phi (0.20 mm)	2.57	4 to 5.5	-45.5 to -47.7
D	2.13 phi (0.23 mm)	1.86	3.5 to 4.5	-43.5 to –46.9
E	2.15 phi (0.23 mm)	1.39	4.5 to 5.5	-49 to –50
F	1.09 phi (0.47 mm)	1.29	4.5 to 5.5	-47.2 to -48
G	2.05 phi (0.24 mm)	2.41	4 to 5.5	-46.5 to -49
H	2.21 phi (0.22 mm)	0.72	3.5 to 4.5	-44.4 to -45.2
J	2.12 phi (0.23 mm)	3.67	3 to 4.5	-42 to -47.4
L	2.05 phi (0.24 mm)	6.13	3 to 5.5	-42.3 to -47
N	1.86 phi (0.28 mm)	5.64	4 to 6	-43.6 to -46.7
O	2.12 phi (0.23 mm)	3.85	1.5 to 4	-40.6 to -43.9
P	2.01 phi (0.25 mm)	2.73	2 to 3.5	-39.5 to -40.5
Q	2.30 phi (0.20 mm)	0.73	1 to 1.5	-35.2 to -35.4
S	1.62 phi (0.32 mm)	1.46	3.5 to 4.5	-43.8 to -44.8
T	1.78 phi (0.29 mm)	0.25	2 to 4	-37.2 to -42

mm - millimeter
MLLW – Mean Low Low Water

Appendix C: Sand Compatibility Analysis (2010)

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1. Introduction. Sands making up the native beach are generally hydraulically sorted with the coarser grain sizes concentrated in the foreshore region, where wave energy is the greatest, and the finer grain sizes located in the offshore areas seaward of the surf zone. In order for the borrow material to be compatible with the native beach sand, the borrow material must contain essentially all of the same grain sizes that exist on the active beach profile of the project area. In this regard, the active beach profile is generally defined in engineering terms as the portion of the profile from the top of the beach berm seaward to depths where significant sand transport by wave energy is negligible. At Topsail Island, the active beach profile appears to end in a water depth of approximately 25 feet below National American Vertical Datum (NAVD). Note that sediment movement in water depths greater than 25 feet below NAVD is known to occur. However, the rate of sediment movement in these deeper depths is relatively small compared to rate of movement in the shallower depths and are therefore of minor importance in the day to day and year to year behavior of the beach profile.

2. Definitions. Definitions are included to provide better understanding of the terminology used in this appendix.

Active zone. The zone that extends from the top of the beach berm seaward to depths where sediment transport induced by waves is negligible.

Beach berm. A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action.

Datum. Any permanent line, plane, or surface, used as a reference datum to which reference datums are referred.

Foreshore. The part of the shore, lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

Grain size. Refers to the mean or effective diameter of individual mineral grains or particles. Grain size analysis passes particles through a series of sieves with known mesh sizes to determine the grain size based on the amount of particles retained or passing a sieve.

Mean high water (MHW). The average height of high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value.

Mean low water (MLW). The average height of low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value.

Mean sea level (MSL). The average height of the surface of the sea for all the stages of the tide over a 19-year period, usually determined from hourly height readings. Not necessarily equal to mean tide level. It is also the average water level that would exist in the absence of tides.

Offshore. The zone extending from the shoreface to the edge of the continental shelf.

Overfill ratio. Used to evaluate the compatibility of sediments and to relate the volume of borrow site sediment required for a project to perform comparably with native beach sand.

Phi scale. A common method to represent grain size distribution. The scale is a logarithmic transformation of the Wentworth grade scale for size classifications of sediment grains based on the negative logarithm to the base 2 of the particle diameter. A phi value is dimensionless and has equivalent millimeter values.

Vibracore. A drill machine driven by a vibrating head assembly to collect sediment samples. Ocean sediment samples are collected by lowering the machine from a floating vessel to the ocean floor.

3. **Grain Size Nomenclature.** Note that the mean grain sizes of the native and borrow area materials are reported in both millimeters (mm) and phi (φ) units in this report where phi is related to the grain size as follows:

$$\varphi = -\ln(d)/\ln$$

(2) where:

d = grain size in millimeters

(mm) ln = natural log

Since the distribution of the sand samples can generally be represented as log-normal distributions, the standard deviations and variances of the particle size distributions are reported in phi units.

4. **Native Beach Sampling and Results.** The characteristics of the native beach material at Topsail Island were determined through an extensive sampling program conducted by the USACE in 2003. Samples were collected from the beach along transects approximately 5,000 feet apart (USACE, 2010; Greenhorne & O'Mara, 2004; OSI, 2004). Only transects 7 through 16 exist within the boundaries for the Surf City/North Topsail Beach project and were evaluated to determine the native beach characteristics. Grab samples were collected by the USACE in 2003 from the along each transect at the surface at the following elevations: Toe of the Dune, Crest of the Berm, Mean High Water (MHW), Mean Sea Level (MSL), Mean Low Water (MLW), and twelve (12) samples collected seaward of MLW starting at elevation -3 feet and continuing at 2 foot depth increments from -4 to -24 feet.

The State of North Carolina implemented new rules in 2007 governing sediment compatibility for beach nourishment. The rules are titled “Technical Standards for Beach Fill Projects” and are found in 15A North Carolina Administrative Code (NCAC) 07H.0312. These rules specify that characterization of the native beach material requires a minimum of thirteen (13) samples be collected along each transect with an equal number of samples collected landward and seaward of mean low water (MLW). Because this rule was implemented after the sampling program at Topsail Island was conducted by USACE, the current data set for transects 7 through 12 contain only four landward samples of MLW. In 2007, Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC) collected two (2) additional samples landward of the MLW from the dune and mid-berm (~ +3 to +5 feet NAVD) along each transect line 13 through 16 to meet this requirement for the North Topsail Beach non-Federal Shore Protection Project. The CPE-NC data for transect lines 13 through 16 has been incorporated into this evaluation performed for the Surf City/North Topsail Beach Federal Shore Protection Project. To comply with the beach fill standard, two (2) additional samples will be required to be collected landward of MLW for each transect line 7 through 12 prior to construction of this project. To be consistent with the samples collected by CPE-NC along transect lines 13 through 16, these additional samples along transect lines 7 through 12 will be collected from the dune and mid-berm (~ +3 to +5 feet NAVD).

To comply with the beach fill standards, only 6 of the 12 samples collected seaward of MLW were combined with the MLW sample and samples landward of MLW to develop the composite characteristics of the native beach material to be used in the compatibility analysis of the borrow material. The grain size distribution of each sample was determined by standard sieve analysis, from which the mean and standard deviation of the grain size distribution of each sample were determined. The samples at each transect line were combined to develop the composite characteristics of the native beach material to be used in the compatibility analysis of the borrow material.

Active Beach Profile Zone

The vertical datum used for the collection of the native beach samples by USACE in 2003 was the National Geodetic Vertical Datum of 1929 (NGVD ’29). The beach fill standards implemented by North Carolina in 2007 adopted the North American Vertical Datum of 1988 (NAVD ’88) as the vertical datum. Therefore, the vertical elevation for near shore samples collected by USACE has been converted to NAVD for consistency in this appendix. The mean grain size and standard deviation of the native samples collected along the transect lines in regards to depth is illustrated on figure E-1. The mean grain size variation with depth is typical of other beaches in North Carolina where coarser material is present in the foreshore area ranging from mean high water (+1.1 NAVD) to around -4 to -5 feet NAVD. The mean grain size gradually decreases seaward from this point. The standard deviation of the particle size distribution is larger at the same depths where the coarser material is present in the foreshore to around -4 to -5 feet NAVD. The standard deviation is gradually smaller seaward of this point.

Composite Characteristics of Native Beach Material

The grain size distribution of each of the samples collected from the transect lines were combined and the average grain size distribution and standard deviation for each transect determined. The individual transect line characteristics are summarized in table E-1. The average grain size distribution and standard deviation for the 10 transect lines (7-16) were then combined to determine the composite grain size distribution and standard deviation for the Surf City/North Topsail Beach study area, which are summarized in table E-2. The composite mean grain size for the Surf City/North Topsail Beach study area is 2.15 phi (0.23 millimeters) with a standard deviation of 0.71 phi (0.61 millimeters).

The mean grain size and standard deviation of each transect line is plotted on figure E-2. The mean grain size for each transect is relatively similar with the exception of transect line 8, which is slightly coarser and the largest percentage of shell present. The standard deviation is also largest at transect line 8 indicating the material is less sorted in this area than along the other transects. Generally, the material appears to be relatively well sorted throughout the study area as illustrated by the small standard deviation with the exception of transect line 8.

5. **Borrow Material Sampling and Results.** The search for borrow material was concentrated in the ocean waters off Topsail Island beginning approximately 1 mile offshore and in water depths of 33 feet Mean Lower Low Water (MLLW) and extending seaward to approximately 6 miles offshore. Details of this offshore search for beach compatible material consisted of a combination of seismic and sonar surveys followed by the collection of vibracores at 369 locations. Boring logs were developed for each vibracore based on visual classifications of the material in the cores. The sand layers in each vibracore were sampled for grain size analysis. The results of the grain size analysis of the vibracore material combined with the seismic bottom profile data, was used to delineate the boundaries of potential offshore borrow areas. Composite grain size characteristics of the material in each of these potential borrow areas were computed for comparison with the composite characteristics of the native beach material.

Borrow Material Vibracores

The investigation was conducted in two major phases. Phase one consisted of the collection of over 315 miles of seismic subbottom profiles performed offshore of Topsail Island, with 173 miles of these miles for the Surf City/North Topsail Beach project. Phase 2 involved the collection of 369 vibracores offshore of Topsail Island, with 208 of these vibracores for the Surf City/North Topsail Beach project. The seismic survey data was analyzed to determine areas where beach quality material of sufficient depth appeared likely.

Based on the interpretation of the seismic data, a vibracore drilling plan was developed to determine the characteristics of the subbottom material. In this regard, the seismic data only provides information on the layering of material and does not provide information of the granular characteristics of the material. The vibracores consist of vibrating a 20-foot long plastic core into the ocean bottom. The plastic core is then split and the material characteristics in the core visually classified. Material collected in the core was sampled and the size distribution of that material was determined through standard sieve analysis. In general, the cores were sampled in two-foot intervals or more frequently if a significant difference in the character of the material was visually apparent. Boring logs and laboratory analysis can be found in the Surf City and North Topsail Beach Coastal Storm Damage Reduction Project 2010 Final Integrated Environmental Impact Statement Appendix C Attachments (USACE, 2010).

Borrow Site Vibracore Analysis

An initial compatibility analysis was conducted of the vibracore logs and sample lab data in 2004. This analysis identified fourteen preliminary borrow areas (G, H, I, J, K, L, M, N, O, P, Q, R, S, and T) for the Surf City/North Topsail Beach project (See Appendix A, Figure A-1). Mid-Atlantic Technology and Environmental Research, Inc completed an archeological resources survey (magnetometer and side-scan sonar) of the preliminary borrow areas in 2005. The survey identified the presence of hard bottom in and around several of the preliminary borrow areas. Due to the presence of significant hard bottom in borrow areas I, K, and M, these borrow areas were eliminated as potential borrow sources.

The grain size characteristics of all of the samples collected from each of the cores within the remaining potential borrow areas are given in tables E-3 through E-18. The grain size characteristics of the borrow area samples were used to develop weighted average composite grain size distribution representative of all of the material in each of the borrow areas. The weighting was based on the thickness of the core represented by a particular sample in each core from which a weighted composite distribution for each core was determined. The weighted average core distributions were used to compute the overall composite characteristics for the entire borrow area. To comply with the NC beach fill standards, tables E-3 through E-18 also identify the amount of fine-grained sediment, defined as smaller than 0.062 millimeters (#230 sieve), the amount of granular sediment, defined as smaller than 4.76 millimeters (#4 sieve) and greater than or equal to 2.0 millimeters (#10 sieve), and the amount of gravel, defined as greater than or equal to 4.76 millimeters (#4 sieve). The final weighted composite characteristics for each of the borrow areas are given in tables E-19 to E-34.

6. Overfill Ratio. The suitability of the borrow material for placement on the beach is based on the overfill ratio. The overfill ratio is computed by numerically comparing the size distribution characteristics of the native beach sand with that in the borrow area and includes an adjustment for the percent of fines in the borrow area. The overfill ratio is primarily based on the assumption that the borrow material will undergo sorting and winnowing once exposed to waves and currents in the littoral zone, with the resulting sorted distribution approaching that of the native sand.

Since borrow material will rarely match the native material exactly, the amount of borrow material needed to result in a net cubic yard of beach fill material will generally be greater than one cubic yard. The excess material needed to yield one net cubic yard of material in place on the beach profile is the overfill ratio. The overfill ratio is defined as the ratio of the volume of borrow material needed to yield one net cubic yard of fill material. For example, if 1.5 cubic yards of fill material is needed to yield one net yard in place, the overfill factor would equal 1.5. The numerical procedure for computing the overfill ratio is contained in a suite of computer programs contained in the Automated Coastal Engineering System (ACES) produced by the U.S. Army Coastal Engineering Research Center. The procedure is also described in the U.S. Army Coastal Engineering Manual EM-1110-2-1100 Part V (July 2003). A summary of the native beach and borrow characteristics, as well as the computed overfill ratios is shown in table E-35.

7. Compatibility and Borrow Sources. The compatibility analysis compares the grain size of the “native or reference beach” with the material in the proposed borrow material. The overfill ratio is the primary indicator of the compatibility of the borrow material to the beach material, with a value of 1.00 indicating that one cubic yard of borrow material is needed to match one cubic yard of beach material. An overfill ratio of up to 1.5 is generally considered acceptable as a match of compatibility. Table E-35 illustrates the overfill ratios for potential borrow areas for the Surf City/North Topsail Beach project.

Prior to implementation of the NC beach fill rules in 2007, eleven (11) offshore borrow areas were identified for the Surf City/North Topsail Beach project and included G, H, J, L, N, O, P, Q, R, S, and T. After re-evaluation of the borrow areas using the new beach fill standards, borrow area R was determined to be well above the silt criteria and was not evaluated further. Excluding borrow area R, the compatibility analysis indicated the overfill ratio for the remaining 10 borrow areas were all below 1.5. Because additional characterization for all borrow areas will be conducted during the design phase, borrow area R has not been included in the volume calculations for material available for the project, but has been retained for future evaluation. With the exclusion of borrow area R, the total estimated volume in the remaining ten borrow areas (G, H, J, L, N, O, P, Q, S, and T) is approximately 27.59 million cubic yards, which is insufficient to meet the required volume for the NED plan of 32.3 million cubic yards.

To address the deficiency of available material for the Surf City/North Topsail Beach project, the six borrow areas identified for the Topsail Beach Federal shore protection project (A, B, C, D, E, and F) were considered. The estimated amount of compatible material in these borrow areas exceeds the Topsail Beach Federal and non-Federal project requirements by approximately 9.68 million cubic yards. Therefore, these borrow areas have been included in the compatibility analysis conducted for the Surf City/North Topsail Beach project in this appendix. The overfill ratios for these six borrow areas are also all below 1.5 with the exception of borrow area C., which was 1.56. Because the overfill ratio for borrow area C was only slightly above 1.5, it has been retained for further evaluation when additional characterization is conducted during the design phase. The additional estimated amount of compatible material in the Topsail Beach borrow areas (A, B, C, D, E, and F) which exceeds the Topsail Beach project requirements (approximately 9.29 million cubic yards) combined with the estimated volume (27.59 million cubic yards) in borrow areas G, H, J, L, N, O, P, Q, S, and T meets the NED project requirements (32.3 million cubic yards).

The composite mean grain size of material in the native beach material and borrow areas is illustrated in table E-35. The composite mean grain size for the borrow areas is typically within 0.03 millimeters of the native beach sand (0.23 millimeters), with the exceptions of borrow areas F, N, S, and T. The mean grain size for these borrow areas is larger than the native beach material with mean grain sizes of 0.47 millimeters, 0.28 millimeters, 0.32 millimeters, and 0.29 millimeters, respectively.

The NC beach fill standards require compatibility of the native beach with borrow sources in regards to the percentage of silt (< 0.062 millimeters), granular sediment, (< 4.76 millimeters and $\geq$ 2.0 millimeters), gravel ($\geq$ 4.76 millimeters), and calcium carbonate. A visual estimate of shell content can be used in lieu of carbonate weight percent for samples collected prior to the effective date of beach fill rules which applies to the Surf City/North Topsail Beach project. The standards require that percent silt, granular sediment, and gravel in borrow material not exceed the amount found in the native beach plus 5 percent and the percent carbonate in borrow material not exceed the amount found in the native beach plus 15 percent. These characteristics for the native beach and borrow material are illustrated in table E-35. The analysis for the native beach material indicates the silt, granular sediment, and gravel content are 1.2 percent, 1.1 percent, and 0.5 percent, respectively. The visual shell content for the native beach is 9 percent. After incorporating the tolerance permitted by the beach fill standards, the silt, granular sediment, gravel, and shell content permitted for borrow areas to be used for the Surf City/North Topsail Beach are less than 6.2 percent, 6.1 percent, 5.5 percent, and 24 percent, respectively.

All of the borrow areas comply with the beach fill standards in regards to the percentage of silt with the exception of borrow areas A (6.6 percent) and L (6.3 percent). Both of these borrow areas exceed the standard slightly by 0.4 and 0.1 percent, respectively. All of the borrow areas comply with the beach fill standards in regards to the percentage of granular sediment with the exception of borrow areas F (7.0 percent) and S (6.6 percent), which exceed the standard by 0.9 and 0.5 percent, respectively. All of the borrow areas comply with the beach fill standards in regards to the percentage of gravel sediment with the exception of borrow areas F (8.5 percent) and P (6.6 percent), which exceed the standard by 3 and 1.1 percent, respectively. All of the borrow areas comply with the beach fill standards in regards to the percentage of shell content (carbonate). Because all borrow areas will be further characterized during the design phase of this project, borrow areas in which the standards were exceeded for the various characteristic (A, F, L, S, and P) have been retained. Additional vibracores will be performed to comply with the beach fill standards of 1 core/acre or 1,000 foot spacing. This additional data will be incorporated into the existing borrow area data to produce the final characteristics of each borrow source, which will be evaluated using the NC beach fill standards to determine compliance.

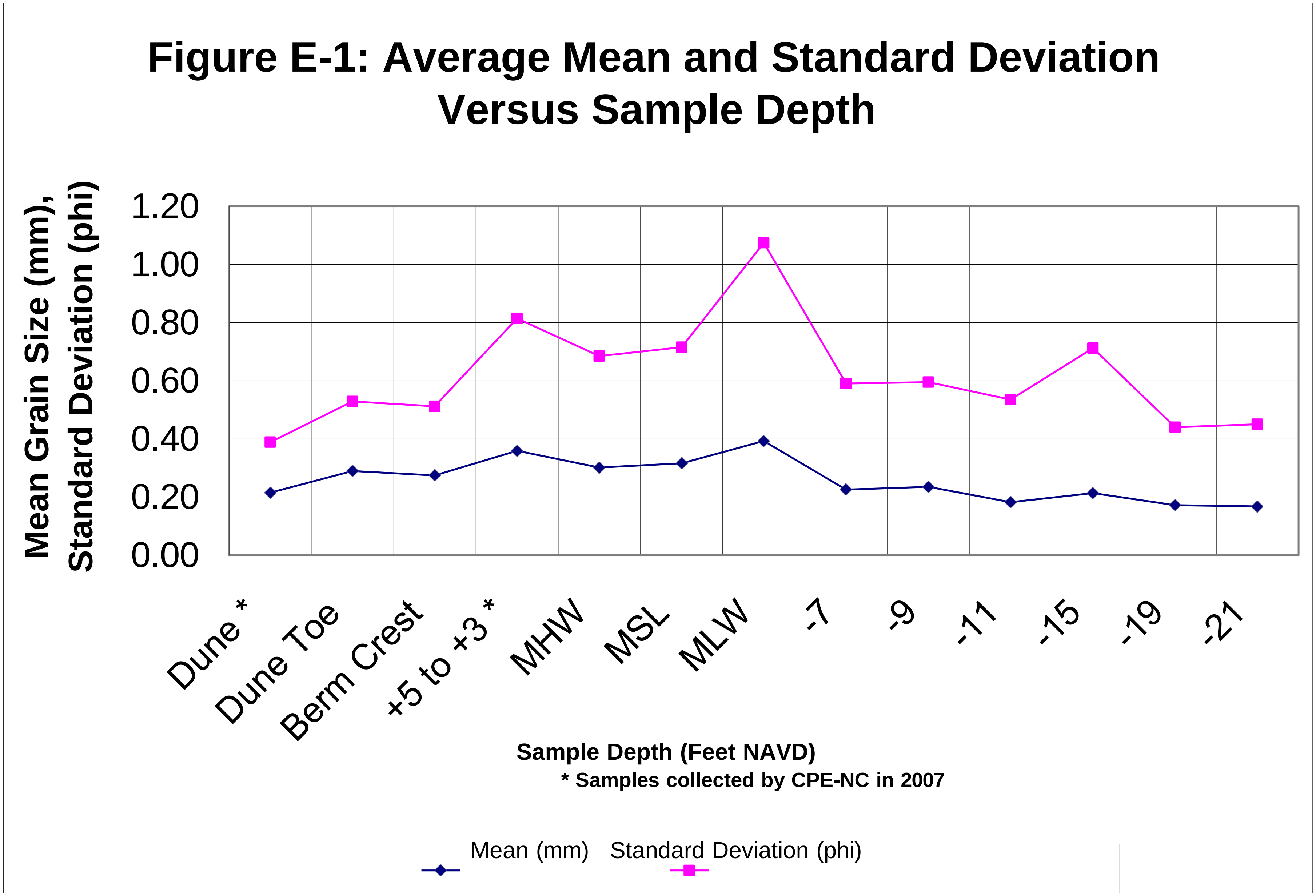
Figure E-1: Average Mean and Standard Deviation Versus Sample Depth
Mean Grain Size (mm), Standard Deviation (phi)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Dune *
Dune Toe
Berm Crest
+5 to +3 *
MHW
MSL
MLW
-7
-9
-11
-15
-19
-21
Sample Depth (Feet NAVD)
* Samples collected by CPE-NC in 2007
Mean (mm)
Standard Deviation (phi)

Figure E-2: Mean Grain Size and Standard Deviation for Transect Lines

Table E-1 <u>Native Beach Samples</u>

Sample Description	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TRANSECT LINE TB-7								
TB-7-TOE	1.89	0.27	0.69	0.62	7.0	0.3	0.9	17
TB-7-CREST	1.53	0.35	0.89	0.54	0.9	0.3	0.0	24
TB-7-MHW	1.61	0.33	0.72	0.61	0.5	0.2	0.0	22
TB-7-MSL	1.47	0.36	1.00	0.50	1.1	0.1	0.0	32
TB-7-MLW	1.37	0.39	1.23	0.43	1.0	3.5	0.2	19
TB-7-6	2.52	0.17	0.41	0.76	1.3	0.1	0.0	5
TB-7-8	2.62	0.16	0.40	0.76	1.0	0.1	0.0	13
TB-7-12	2.43	0.19	0.46	0.73	1.1	0.6	0.1	8
TB-7-14	2.57	0.17	0.47	0.72	1.8	2.0	0.1	5
TB-7-18	2.52	0.17	0.42	0.75	1.3	0.0	1.0	5
TB-7-20	2.61	0.16	0.42	0.75	2.1	0.0	0.0	2
TRANSECT LINE TB-8								
TB-8-TOE	0.93	0.52	0.59	0.67	0.5	0.1	0.0	35
TB-8-CREST	1.50	0.35	0.40	0.76	1.2	4.4	1.4	20
TB-8-MHW	1.59	0.33	0.92	0.53	1.3	3.1	0.2	17
TB-8-MSL	1.53	0.35	0.81	0.57	0.6	0.2	0.0	20
TB-8-MLW	0.52	0.70	1.97	0.26	0.8	18.3	7.9	30
TB-8-6	2.01	0.25	0.65	0.64	1.0	0.3	0.0	13
TB-8-8	2.54	0.17	0.47	0.72	0.8	0.2	0.0	7
TB-8-12	2.49	0.18	0.44	0.74	1.4	0.1	0.0	6
TB-8-14	2.52	0.17	0.46	0.73	1.2	2.4	0.2	4
TB-8-18	2.57	0.17	0.41	0.75	1.7	0.0	0.0	6
TB-8-20	2.64	0.16	0.44	0.74	2.0	0.1	0.0	7
TRANSECT LINE TB-9								
TB-9-TOE	2.08	0.24	0.42	0.75	0.8	0.1	0.0	5
TB-9-CREST	2.17	0.22	0.40	0.76	0.9	0.0	0.0	6
TB-9-MHW	1.72	0.30	0.81	0.57	1.4	3.0	0.0	15
TB-9-MSL	1.44	0.37	1.19	0.44	0.7	2.3	0.0	18
TB-9-MLW	0.52	0.70	2.08	0.24	0.9	27.3	6.1	20
TB-9-6	2.43	0.19	0.44	0.74	1.3	0.1	0.0	9
TB-9-8	2.51	0.17	0.45	0.73	1.0	0.1	0.0	8
TB-9-12	2.48	0.18	0.55	0.68	1.6	2.2	0.0	9
TB-9-14	2.53	0.17	0.44	0.74	1.3	0.5	0.4	5
TB-9-18	2.57	0.17	0.43	0.74	1.9	0.1	0.0	3
TB-9-20	2.64	0.16	0.41	0.75	2.3	0.1	0.0	3
TRANSECT LINE TB-10								
TB-10-TOE	1.36	0.39	1.04	0.49	0.6	2.8	0.0	13
TB-10-CREST	1.87	0.27	0.55	0.68	0.8	0.0	0.0	12
TB-10-MHW	2.04	0.24	0.44	0.74	1.2	0.0	0.0	7
TB-10-MSL	2.04	0.24	0.47	0.72	1.1	0.1	0.0	6
TB-10-MLW	1.79	0.29	0.90	0.54	1.0	0.5	0.2	16
TB-10-6	2.59	0.17	0.39	0.76	1.4	0.0	0.0	5
TB-10-8	2.61	0.16	0.49	0.71	1.6	0.1	0.0	4
TB-10-12	2.52	0.17	0.51	0.70	1.8	0.2	0.0	5
TB-10-14	2.41	0.19	0.53	0.69	1.8	2.1	0.7	7
TB-10-18	2.45	0.18	0.42	0.75	2.2	0.5	0.3	4
TB-10-20	2.49	0.18	0.44	0.74	2.8	0.1	0.1	5

Sample Description	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TRANSECT LINE TB-11								
TB-11-TOE	1.98	0.25	0.40	0.76	0.6	0.1	0.0	5
TB-11-CREST	2.10	0.23	0.39	0.76	0.3	0.0	0.0	5
TB-11-MHW	1.45	0.37	1.07	0.48	0.8	1.6	0.0	13
TB-11-MSL	1.35	0.39	1.08	0.47	0.6	0.1	0.2	30
TB-11-MLW	1.79	0.29	0.74	0.60	1.3	0.3	0.0	15
TB-11-6	2.34	0.20	0.46	0.72	1.1	0.3	0.0	6
TB-11-8	1.53	0.35	0.47	0.72	0.6	0.3	0.0	5
TB-11-12	1.62	0.32	0.53	0.69	1.3	0.4	0.1	7
TB-11-14	1.63	0.32	0.43	0.74	1.4	2.1	0.2	8
TB-11-18	1.70	0.31	0.42	0.75	1.5	0.3	0.1	4
TB-11-20	1.67	0.31	0.42	0.75	1.2	0.2	0.9	6
TRANSECT LINE TB-12								
TB-12-TOE	1.98	0.25	0.43	0.74	0.5	0.0	0.0	4
TB-12-CREST	2.10	0.23	0.43	0.74	0.1	0.0	0.0	6
TB-12-MHW	2.01	0.25	0.51	0.70	0.7	0.0	0.0	10
TB-12-MSL	1.92	0.26	0.43	0.74	0.5	0.0	0.0	7
TB-12-MLW	1.29	0.41	1.19	0.44	1.7	3.2	1.1	31
TB-12-6	2.43	0.19	0.44	0.74	0.8	0.4	0.0	5
TB-12-8	2.44	0.18	0.41	0.75	0.0	1.0	0.0	6
TB-12-12	2.47	0.18	0.48	0.72	1.6	0.6	0.8	7
TB-12-14	0.89	0.54	2.71	0.15	0.9	4.3	17.8	28
TB-12-18	2.60	0.16	0.41	0.75	2.2	0.0	0.0	4
TB-12-20	2.52	0.17	0.46	0.73	1.6	0.7	0.1	6
TRANSECT LINE TB-13								
TB-13-DUNE *	2.17	0.22	0.42	0.75	0.3	0.0	0.0	0
TB-13-TOE	1.99	0.25	0.48	0.72	0.8	0.1	0.0	10
TB-13-CREST	1.65	0.32	0.70	0.61	1.1	0.0	0.1	14
TB-13 +5 *	1.06	0.48	1.04	0.49	0.6	0.0	2.4	0
TB-13-MHW	1.71	0.31	0.68	0.63	0.5	0.0	0.1	12
TB-13-MSL	1.72	0.30	0.68	0.63	0.0	0.0	0.0	15
TB-13-MLW	1.92	0.26	0.58	0.67	1.2	0.0	0.0	12
TB-13-6	2.48	0.18	0.49	0.71	0.9	0.3	0.0	5
TB-13-8	2.43	0.19	0.56	0.68	1.0	0.3	0.0	6
TB-13-12	2.50	0.18	0.52	0.70	2.3	0.6	0.1	6
TB-13-14	2.53	0.17	0.57	0.67	2.7	0.4	0.0	6
TB-13-18	2.54	0.17	0.50	0.71	2.0	0.4	0.0	4
TB-13-20	2.60	0.17	0.50	0.70	2.6	0.1	0.0	5
TRANSECT LINE TB-14								
TB-14-DUNE *	2.35	0.20	0.36	0.78	0.21	0.0	0.0	0
TB-14-TOE	2.11	0.23	0.37	0.77	0.4	0.2	0.0	5
TB-14-CREST	1.76	0.30	0.64	0.64	0.4	0.2	0.0	9
TB-14 +3 *	2.28	0.21	0.32	0.80	0.8	0.0	0.0	0
TB-14-MHW	1.99	0.25	0.43	0.74	0.5	0.0	0.0	6
TB-14-MSL	1.94	0.26	0.44	0.74	0.4	0.0	0.0	6
TB-14-MLW	1.78	0.29	0.63	0.65	1.4	0.0	0.0	13
TB-14-6	2.40	0.19	0.51	0.70	1.0	0.2	0.0	6
TB-14-8	2.35	0.20	0.53	0.69	0.3	0.1	0.0	5
TB-14-12	2.38	0.19	0.57	0.67	1.2	0.4	0.6	5
TB-14-14	2.43	0.19	0.44	0.74	0.8	0.3	0.0	4
TB-14-18	2.50	0.18	0.44	0.74	1.7	0.3	0.0	2
TB-14-20	2.59	0.17	0.46	0.73	2.3	0.3	0.0	3

* Samples were collected by CPE-NC Inc for the North Topsail Non-Federal Shore Protection Project in 2007.

Sample Description	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TRANSECT LINE TB-15								
TB-15-DUNE *	2.28	0.21	0.35	0.79	0.2	0.0	0.0	0
TB-15-TOE	2.10	0.23	0.48	0.72	0.5	0.0	0.0	6
TB-15-CREST	2.19	0.22	0.32	0.80	0.1	0.0	0.0	2
TB-15 +3 *	0.86	0.55	1.58	0.33	0.5	0.1	0.0	0
TB-15-MHW	1.87	0.27	0.56	0.68	0.4	0.0	0.0	3
TB-15-MSL	1.82	0.28	0.65	0.64	0.9	0.0	0.0	6
TB-15-MLW	1.77	0.29	0.86	0.55	0.9	0.2	0.0	10
TB-15-6	2.52	0.17	0.47	0.72	1.0	0.1	0.0	3
TB-15-8	0.58	0.67	1.23	0.43	1.1	8.5	2.7	28
TB-15-12	2.55	0.17	0.57	0.67	2.2	0.5	0.4	4
TB-15-14	2.56	0.17	0.53	0.69	1.9	1.3	0.8	3
TB-15-18	2.63	0.16	0.47	0.72	2.5	0.0	0.0	1
TB-15-20	2.65	0.16	0.46	0.73	2.3	0.0	0.0	3
TRANSECT LINE TB-16								
TB-16-DUNE *	2.08	0.24	0.43	0.74	0.2	0.0	0.0	0
TB-16-TOE	2.10	0.23	0.38	0.77	0.2	0.0	0.0	4
TB-16-CREST	2.09	0.24	0.40	0.76	0.1	0.0	0.0	4
TB-16 +4 *	2.31	0.20	0.32	0.80	0.5	0.0	0.0	0
TB-16-MHW	1.79	0.29	0.71	0.61	0.1	0.6	0.0	9
TB-16-MSL	2.00	0.25	0.42	0.75	0.6	0.0	0.0	5
TB-16-MLW	2.00	0.25	0.56	0.68	1.1	2.7	0.5	7
TB-16-6	0.84	0.56	1.63	0.32	0.4	10.5	0.4	27
TB-16-8	2.02	0.25	0.96	0.51	0.9	1.1	0.5	12
TB-16-12	2.42	0.19	0.71	0.61	1.5	1.5	0.3	7
TB-16-14	2.64	0.16	0.55	0.68	1.8	1.5	0.0	4
TB-16-18	2.67	0.16	0.48	0.72	1.1	0.0	0.0	3
TB-16-20	2.71	0.15	0.49	0.71	2.2	0.0	0.0	3

* Samples were collected by CPE-NC Inc for the North Topsail Non-Federal Shore Protection Project in 2007.

Table E-2 Composite Characteristics for Native Beach

Transect Line	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TB-7	2.12	0.23	0.81	0.57	1.7	0.7	0.2	14
TB-8	1.93	0.26	1.00	0.50	1.1	2.7	0.9	15
TB-9	2.22	0.21	0.67	0.63	1.3	3.2	0.6	9
TB-10	2.23	0.21	0.63	0.65	1.8	0.6	0.1	8
TB-11	2.17	0.22	0.63	0.64	1.0	0.5	0.1	9
TB-12	2.20	0.22	0.63	0.64	1.0	0.9	1.8	10
TB-13	2.09	0.23	0.76	0.59	1.2	0.4	1.2	7
TB-14	2.22	0.22	0.56	0.68	0.9	0.1	0.0	5
TB-15	2.09	0.23	0.78	0.58	1.1	0.8	0.3	5
TB-16	2.20	0.22	0.64	0.64	0.8	1.4	0.1	7
Native Beach Composite Data	**2.15**	**0.23**	**0.71**	**0.61**	**1.2**	**1.1**	**0.5**	**9**

Table E-3 <u>Borings for Borrow Area G</u>

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-254	1	-49	-51	2	2.45	0.18	0.43	0.74	1.6	0.3	0.0	3
	2	-51	-53	2	1.81	0.29	1.59	0.33	14.0	5.7	5.1	9
	3	-53	-54	1	1.33	0.40	1.62	0.33	6.8	5.4	8.8	1
		EL -49 to -54		D= 5	2.09	0.23	0.90	0.54	7.6	3.5	3.8	5
TI-03-V-256	1	-47.3	-48.8	1.5	2.09	0.23	0.62	0.65	1.0	0.8	1.6	7
	2	-48.8	-49.3	0.5	2.08	0.24	0.63	0.65	1.1	0.9	3.0	7
		EL -47.3 to -49.3		D=2	2.09	0.23	0.62	0.65	1.1	0.8	2.0	7
TI-03-V-257	1	-47.5	-50	2.5	1.92	0.26	1.09	0.47	2.4	3.2	8.4	15
	2	-50	-50.5	0.5	2.48	0.18	0.96	0.52	11.1	1.7	1.1	6
		EL -47.5 to -50.5		D= 3	2.04	0.24	0.97	0.51	3.9	2.9	7.2	14
TI-03-V-258	1	-46.5	-47.8	1.3	1.31	0.40	1.83	0.28	1.2	3.4	12.4	18
	2	-47.8	-49.3	1.5	0.75	0.60	2.70	0.15	4.2	10.0	18.5	37
		EL -46.5 to -49.3		D= 2.8	0.89	0.54	2.48	0.18	2.8	6.9	15.7	28
TI-03-V-275	1	-47.7	-50	2.3	2.65	0.16	0.60	0.66	9.3	0.9	2.9	6
	2	-50	-53.2	3.2	2.57	0.17	0.40	0.76	4.2	0.0	0.0	2
	3	-53.2	-55.5	0	2.87	0.14	0.71	0.61	14.4	0.2	0.0	2
	4	-55.5	-56	0	2.37	0.19	1.82	0.28	16.2	5.4	5.5	7
		EL -47.7 to -53.2		D=5.5	2.58	0.17	0.43	0.74	6.3	0.4	1.2	4

Table E-4 Borings for Borrow Area H

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-260	1	-44.4	-46	1.6	1.85	0.28	0.99	0.50	1.3	2.7	5.9	14
	2	-46	-46.6	0.6	2.61	0.16	0.55	0.68	9.6	0.8	0.6	3
		EL -44.4 to -46.6		D= 2.2	2.07	0.24	0.87	0.55	3.6	2.2	4.5	11

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-273	1	-45.2	-47.5	2.3	2.23	0.21	0.60	0.66	2.2	2.0	1.8	7
	2	-47.5	-50	2.5	2.30	0.20	0.52	0.70	2.0	0.6	0.0	4
	3	-50	-52	0	2.56	0.17	0.39	0.76	4.4	0.6	0.1	3
	4	-52	-54	0	2.76	0.15	0.23	0.86	2.7	0.0	0.0	1
	5	-54	-55.7	0	2.58	0.17	0.36	0.78	2.1	0.0	0.0	1
	6	-55.7	-56.2	0	2.56	0.17	0.37	0.77	2.4	0.0	0.0	0
		EL -45.2 to -50		D=4.8	2.27	0.21	0.55	0.68	2.1	1.3	0.9	5

Table E-5 Borings for Borrow Area J

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-98	**1**	**-45.5**	**-48.3**	**2.8**	**2.13**	**0.23**	**0.73**	**0.60**	**5.2**	**1.3**	**0.5**	**11**
	2	-48.3	-51	0	4.28	0.05	3.78	0.07	22.1	5.2	1.5	15
	3	-51	-53	0	2.67	0.16	0.79	0.58	15.6	3.0	0.4	10
	4	-53	-55.5	0	3.63	0.08	2.09	0.23	18.6	1.5	0.6	6
	5	-55.5	-58	0	2.48	0.18	0.45	0.73	9.4	2.2	0.4	7
	6	-58	-61	0	2.50	0.18	0.40	0.76	6.6	0.1	0.0	3
	7	-61	-64	0	2.50	0.18	0.41	0.75	8.0	0.5	0.0	4
	8	-64	-65.5	0	2.57	0.17	0.48	0.71	12.6	0.1	0.0	2
		EL -45.5 to -48.3		**D= 2.8**	**2.13**	**0.23**	**0.73**	**0.60**	**5.2**	**1.3**	**0.5**	**11**
TI-03-V-99	**1**	**-46.7**	**-50**	**3.3**	**2.46**	**0.18**	**0.44**	**0.73**	**9.6**	**1.3**	**0.1**	**6.0**
	2	**-50**	**-53**	**3**	**2.45**	**0.18**	**0.47**	**0.72**	**11.4**	**2.1**	**0.3**	**8.0**
	3	**-53**	**-55**	**2**	**2.43**	**0.18**	**0.40**	**0.76**	**6.2**	**0.4**	**0.2**	**4.0**
	4	-55	-58.5	0	3.05	0.12	1.33	0.40	16.8	2.2	0.9	9.0
	5	-58.5	-61	0	2.48	0.18	0.40	0.76	6.4	0.3	0.0	3.0
	6	-61	-63	0	2.53	0.17	0.42	0.75	10.7	0.1	0.0	2.0
	7	-63	-66.2	0	2.49	0.18	0.40	0.76	7.6	0.0	0.0	2.0
	8	-66.2	-66.7	0	2.50	0.18	0.41	0.75	8.8	0.1	0.0	1.0
		EL -46.7 to -55		**D=8.3**	**2.45**	**0.18**	**0.44**	**0.74**	**9.5**	**1.4**	**0.2**	**6.2**
TI-03-V-102	**1**	**-45**	**-47**	**2**	**1.70**	**0.31**	**1.23**	**0.43**	**2.4**	**5.8**	**1.7**	**19**
	2	**-47**	**-48**	**1**	**2.22**	**0.21**	**0.63**	**0.65**	**2.3**	**1.9**	**0.4**	**11**
	3	-48	-51	0	2.51	0.18	0.78	0.58	14.4	3.4	0.8	12
	4	-51	-54	0	2.52	0.17	0.42	0.75	9.7	0.4	0.1	3
	5	-54	-57	0	2.52	0.17	0.42	0.75	10.1	0.0	0.0	2
	6	-57	-59.3	2.3	2.60	0.17	0.51	0.70	12.6	0.1	0.0	2
		EL -45 to -48		**D=3**	**1.86**	**0.27**	**1.05**	**0.48**	**2.3**	**4.5**	**1.3**	**16**

Table E-5 Borings for Borrow Area J Continued

Boring Number	Layer Number	Layer Depth (ft)		Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
		Top	Bottom									
TI-03-V-103	**1**	**-47.4**	**-50**	**2.6**	**2.29**	**0.20**	**0.58**	**0.67**	**2.8**	**1.6**	**0.2**	**10**
	2	-50	-53	0	2.57	0.17	0.59	0.67	13.5	1.7	0.6	8
	3	-53	-55	0	3.17	0.11	1.40	0.38	18.0	0.4	0.0	3
	4	-55	-57	0	2.42	0.19	4.39	0.05	26.0	4.6	15.2	1
	5	-57	-59	0	3.65	0.08	1.66	0.32	32.8	3.5	1.7	2
	6	-59	-59.7	0	3.45	0.09	0.97	0.51	26.9	1.2	0.0	4
		EL -47.4 to -50		**D=2.6**	**2.29**	**0.20**	**0.58**	**0.67**	**2.8**	**1.6**	**0.2**	**10**
TI-03-V-270A	**1**	**-46.3**	**-48.3**	**2**	**2.00**	**0.25**	**0.81**	**0.57**	**1.5**	**3.0**	**1.1**	**9**
	2	-48.3	-50.5	0	3.19	0.11	0.78	0.58	17.7	0.1	0.1	1
	3	-50.5	-52.5	0	3.28	0.10	0.73	0.60	18.6	0.1	0.0	1
	4	-52.5	-54.8	0	3.21	0.11	0.72	0.61	16.9	0.5	0.0	1
		EL -46.3 to -48.3		**D=2**	**2.00**	**0.25**	**0.81**	**0.57**	**1.5**	**3.0**	**1.1**	**9**
TI-03-V-281	**1**	**-44**	**-45.5**	**1.5**	**1.73**	**0.30**	**0.99**	**0.50**	**1.5**	**4.4**	**1.9**	**15**
	2	**-45.5**	**-47.4**	**1.9**	**2.20**	**0.22**	**0.54**	**0.69**	**1.1**	**1.0**	**0.2**	**6**
	3	-47.4	-49	0	1.95	0.26	1.94	0.26	15.6	8.2	3.3	19
	4	-49	-51	0	3.29	0.10	2.55	0.17	19.1	5.9	1.8	13
	5	-51	-53	0	2.38	0.19	1.02	0.49	14.7	3.4	6.1	11
	6	-53	-55.2	0	3.27	0.10	1.69	0.31	18.4	2.8	1.7	11
	7	-55.2	-55.7	0	3.06	0.12	1.36	0.39	17.5	3.0	1.5	10
		EL -44 to -47.4		**D=3.4**	**2.02**	**0.25**	**0.72**	**0.61**	**1.2**	**2.5**	**1.0**	**10**
TI-03-V-283	**1**	**-42.4**	**-44**	**1.6**	**1.58**	**0.34**	**1.16**	**0.45**	**2.2**	**5.3**	**2.8**	**10**
	2	**-44**	**-45.6**	**1.6**	**2.15**	**0.22**	**0.57**	**0.67**	**2.0**	**2.1**	**0.8**	**7**
	3	-45.6	-48.5	0	1.87	0.27	1.82	0.28	15.3	8.4	3.1	17
	4	-48.5	-51	0	3.35	0.10	1.75	0.30	18.8	2.2	0.2	3
	5	-51	-53.5	0	2.64	0.16	0.72	0.61	14.7	2.9	2.6	8
	6	-53.5	-54.6	0	2.55	0.17	0.56	0.68	12.9	2.6	0.5	5
		EL -42.4 to -45.6		**D=3.2**	**1.87**	**0.27**	**0.88**	**0.54**	**2.1**	**3.7**	**1.8**	**9**

Table E-5 Borings for Borrow Area J Continued

Boring Number	Layer Number	Layer Depth (ft)		Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
		Top	Bottom									
TI-03-V-286	**1**	**-42**	**-44.2**	**2.2**	**1.89**	**0.27**	**0.90**	**0.53**	**2.6**	**1.8**	**3.3**	**11**
	2	**-44.2**	**-46**	**1.8**	**1.26**	**0.42**	**2.24**	**0.21**	**12.3**	**7.0**	**11.7**	**17**
	3	-46	-49	0	2.15	0.23	2.00	0.25	16.1	5.7	7.4	12
	4	-49	-51.5	0	-0.21	1.15	4.86	0.03	15.8	9.6	33.4	1
	5	-51.5	-54	0	1.98	0.25	3.62	0.08	23.1	16.3	10.6	1
	6	-54	-55	0	-0.39	1.31	4.71	0.04	15.3	5.3	41.3	1
		EL -42 to -46		**D=4**	**1.85**	**0.28**	**1.15**	**0.45**	**7.0**	**1.8**	**3.3**	**14**

Table E-6 Borings for Borrow Area L

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-91	1	-46.8	-48	1.2	2.00	0.25	0.78	0.58	1.4	1.8	1.1	7
	2	-48	-50.3	2.3	1.26	0.42	2.61	0.16	10.1	5.7	14.1	26
		EL -46.8 to -50.3		D= 3.5	1.61	0.33	1.69	0.31	7.1	4.4	9.6	19
TI-03-V-93	1	-46.7	-49	2.3	2.15	0.23	0.83	0.56	8.5	3.8	0.8	15
	2	-49	-51	0	2.45	0.18	0.96	0.51	14.7	3.7	0.6	11
	3	-51	-53	0	2.54	0.17	0.49	0.71	11.8	0.9	0.3	4
	4	-53	-54.2	0	2.52	0.17	0.44	0.74	9.5	1.1	0.1	5
	5	-54.2	-57	0	2.62	0.16	0.56	0.68	12.7	0.4	0.0	3
	6	-57	-60	0	3.63	0.08	2.03	0.24	19.6	1.2	0.4	7
	7	-60	-63	0	3.66	0.08	2.08	0.24	20.3	1.1	0.4	2
	8	-63	-65.2	0	3.84	0.07	2.31	0.20	23.2	4.0	0.0	2
		EL -46.7 to -49		D=2.3	2.15	0.23	0.83	0.56	8.5	3.8	0.8	15
TI-03-V-95	1	-47	-50	3	2.49	0.18	0.45	0.73	9.8	1.6	0.3	8
	2	-50	-53	3	2.49	0.18	0.45	0.73	10.2	1.6	0.5	9
	3	-53	-56	3	2.49	0.18	0.41	0.75	7.4	0.7	0.0	5
	4	-56	-58	2	2.53	0.17	0.38	0.77	4.7	0.1	0.0	3
	5	-58	-60.8	2.8	2.54	0.17	0.42	0.75	8.8	0.2	0.0	3
	6	-60.8	-63.5	0	3.74	0.07	2.23	0.21	22.1	2.8	3.5	2
	7	-63.5	-64.3	0	2.33	0.20	4.41	0.05	23.8	9.6	15.1	1
		EL -47 to -60.8		D=13.8	2.50	0.18	0.42	0.75	8.4	0.9	0.2	6
TI-03-V-341	1	-44.2	-46.5	2.3	1.97	0.26	0.96	0.51	5.1	3.0	0.5	7
	2	-46.5	-48.5	2	2.31	0.20	0.71	0.61	7.8	1.9	1.0	5
	3	-48.5	-51	0	2.60	0.16	0.65	0.64	13.4	2.2	6.7	1
	4	-51	-53.5	0	2.54	0.17	0.45	0.73	10.5	1.2	1.4	2
	5	-53.5	-56	0	2.59	0.17	0.57	0.68	12.8	1.4	4.8	3
	6	-56	-58.2	0	0.61	0.65	3.20	0.11	10.7	5.6	26.3	5
		EL -44.2 to -48.5		D=4.3	2.12	0.23	0.88	0.54	6.3	2.5	0.7	6

Table E-6 Borings for Borrow Area L Continued

Boring Number	Layer Number	Layer Depth (ft)		Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
		Top	Bottom									
TI-03-V-342	1	-44.3	-46.3	2	1.89	0.27	1.04	0.49	3.8	5.6	2.8	15
	2	-46.3	-48.5	0	1.97	0.26	1.46	0.36	12.7	6.4	1.4	14
	3	-48.5	-51.5	0	3.52	0.09	3.28	0.10	23.1	5.6	1.8	17
	4	-51.5	-54.5	0	1.92	0.26	1.81	0.28	14.5	7.8	1.6	11
	5	-54.5	-57	0	1.52	0.35	2.44	0.18	14.5	8.5	9.9	11
	6	-57	-59.1	0	2.78	0.15	1.28	0.41	16.4	4.5	3.6	4
	7	-59.1	-61	0	2.69	0.16	0.64	0.64	13.8	1.3	0.2	2
	8	-61	-63.5	0	2.63	0.16	0.49	0.71	10.5	1.5	0.1	3
	9	-63.5	-64.3	0	-1.18	2.27	3.63	0.08	7.6	6.8	48.4	2
		EL -44.3 to -46.3		D=2	1.89	0.27	1.04	0.49	3.8	5.6	2.8	15
TI-03-V-343	1	-46	-48	1.5	2.37	0.19	0.48	0.72	2.3	0.7	0.0	2
	2	-48	-50	1.5	2.23	0.21	0.62	0.65	1.3	1.7	0.8	5
	3	-50	-51	0	2.53	0.17	0.43	0.74	9.2	0.4	0.4	1
	4	-51	-54	0	2.65	0.16	0.55	0.68	12.7	0.2	0.0	2
	5	-54	-58.3	0	2.73	0.15	0.63	0.65	14.2	0.8	0.0	4
		EL -46 to -51		D=5	2.37	0.19	0.50	0.71	3.3	1.0	0.4	3
TI-03-V-344	1	-45.7	-47.5	1.8	0.74	0.60	2.31	0.20	1.4	8.2	14.4	22
	2	-47.5	-48	0.5	1.36	0.39	1.44	0.37	2.3	2.9	11.5	23
		EL -45.7 to -48		D=2.3	0.81	0.57	2.23	0.21	1.6	7.0	13.8	22
TI-03-V-345	1	-42.3	-44.5	2.2	1.70	0.31	0.93	0.52	1.6	2.0	1.1	14
	2	-44.5	-45.3	0.8	1.42	0.37	1.35	0.39	2.2	5.0	4.9	18
		EL -42.3 to -45.3		D=3	1.65	0.32	1.01	0.50	1.8	2.8	2.1	15
TI-03-V-346	1	-42.5	-44	1.5	1.74	0.30	1.14	0.45	3.6	3.8	3.9	13
	2	-44	-45.5	1.5	2.25	0.21	0.79	0.58	11.7	2.9	5.9	13
	3	-45.5	-47	0	2.56	0.17	0.58	0.67	13.0	1.6	2.0	1
	4	-47	-48.5	0	2.66	0.16	0.58	0.67	12.9	0.9	1.5	2
	5	-48.5	-51	0	0.77	0.59	2.92	0.13	13.7	5.8	20.0	1
	6	-51	-52	0	0.67	0.63	3.42	0.09	13.4	7.4	29.1	3
		EL -42.5 to -45.5		D=3	1.93	0.26	1.09	0.47	7.6	3.4	4.9	13

Table E-6 Borings for Borrow Area L Continued

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-351	1	-44.5	-45.5	1	-0.43	1.34	2.67	0.16	2.2	14.6	27.9	28
	2	-45.5	-47.3	1.8	2.60	0.16	0.58	0.67	10.1	3.4	0.8	10
	3	-47.3	-49.5	0	3.08	0.12	1.28	0.41	17.7	2.0	0.4	5
	4	-49.5	-51.5	0	2.66	0.16	1.01	0.50	15.3	1.7	8.0	1
		EL -44.5 to -47.3		D=2.8	1.31	0.40	2.13	0.23	7.3	7.4	10.5	16

Table E-7 Borings for Borrow Area N

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-63	1	-45.9	-47	1.1	2.18	0.22	0.52	0.70	0.7	0.5	0.3	6
	2	-47	-48.9	1.9	1.82	0.28	0.99	0.50	1.5	3.2	7.5	18
		EL -45.9 to -48.9		D= 3	2.08	0.24	0.63	0.65	1.2	2.2	4.9	14
TI-03-V-65	1	-45.7	-47	1.3	2.29	0.20	0.47	0.72	1.2	0.3	0.0	6
	2	-47	-48.5	1.5	2.38	0.19	0.46	0.73	1.3	0.9	0.3	6
	3	-48.5	-50.5	2	2.39	0.19	0.40	0.76	2.0	0.6	1.5	9
	4	-50.5	-51.2	0.7	2.41	0.19	0.42	0.75	1.3	0.2	0.0	4
		EL -45.7 to -51.2		D=5.5	2.37	0.19	0.43	0.74	1.5	0.5	0.6	7
TI-03-V-68	1	-46.7	-48.5	1.8	2.38	0.19	0.46	0.73	1.4	0.9	0.2	5
	2	-48.5	-50.5	2	1.55	0.34	1.20	0.43	7.5	4.8	4.9	3
	3	-50.5	-52	1.5	0.24	0.85	2.86	0.14	10.0	4.9	19.5	1
	4	-52	-52.7	0.7	1.73	0.30	0.85	0.55	6.0	2.7	5.7	1
		EL -46.7 to -52.7		D=6	1.71	0.31	1.20	0.44	6.1	3.4	4.8	3
TI-03-V-69	1	-43.6	-45	1.4	2.05	0.24	0.73	0.60	0.7	2.3	3.3	13
	2	-45	-46.8	1.8	0.97	0.51	1.96	0.26	1.2	8.2	10.4	30
	3	-46.8	-47.3	0.5	0.61	0.66	2.67	0.16	2.1	6.0	18.5	34
		EL -43.6 to -47.3		D=3.7	1.31	0.40	1.71	0.31	1.1	5.7	8.8	24
TI-03-V-70	1	-44.8	-47	2.2	1.27	0.42	1.36	0.39	4.6	4.2	7.1	19
	2	-47	-47.8	0.8	1.06	0.48	1.99	0.25	10.6	11.3	6.4	29
	3	-47.8	-49.3	1.5	1.74	0.30	0.98	0.51	5.0	1.3	11.4	1
	4	-49.3	-49.8	0.5	1.74	0.30	1.32	0.40	10.5	3.6	8.7	8
		EL -44.8 to -49.8		D=5	1.33	0.40	1.46	0.36	6.3	4.4	8.4	14

Table E-7 <u>Borings for Borrow Area N</u>

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-72	1	-43.6	-45.5	1.9	0.71	0.61	1.29	0.41	0.9	6.5	6.7	21
	2	-45.5	-46.4	0.9	0.04	0.97	2.63	0.16	1.5	7.7	19.9	15
		EL -43.6 to -46.4		D=2.8	0.54	0.69	1.64	0.32	1.1	6.9	10.9	19
TI-03-V-74	1	-46.2	-48	1.8	2.31	0.20	0.48	0.71	1.1	1.4	0.1	5
	2	-48	-50	2	2.38	0.19	0.50	0.71	2.3	0.9	0.3	7
	3	-50	-51.7	1.7	1.08	0.47	2.17	0.22	6.9	8.3	10.8	18
		EL -46.2 to -51.7		D=5.5	2.20	0.22	0.67	0.63	3.3	3.4	3.5	10
TI-03-V-77	1	-45.7	-48	2.3	2.23	0.21	0.57	0.67	1.4	1.5	0.9	7
	2	-48	-49.2	0	-0.30	1.23	2.82	0.14	8.8	15.4	26.8	16
		EL -45.7 to -48		D=2.3	2.23	0.21	0.57	0.67	1.4	1.5	0.9	7
TI-03-V-78	1	-44.8	-46.8	2	1.41	0.38	1.82	0.28	3.3	6.9	8.1	15
	2	-46.8	-48.3	1.5	2.73	0.15	0.42	0.75	7.5	0.1	0.0	2
	3	-48.3	-48.8	0.5	2.53	0.17	0.38	0.77	2.3	0.0	0.0	2
		EL -44.8 to -48.8		D=4	2.38	0.19	0.65	0.64	4.8	3.5	4.1	9
TI-03-V-79	1	-44.1	-46.4	2.3	2.03	0.24	0.60	0.66	1.6	0.5	0.1	8
	2	-46.4	-47.5	0	-0.44	1.35	2.27	0.21	6.4	15.5	38.4	2
		EL -44.5 to -46.4		D=2.3	2.03	0.24	0.60	0.66	1.6	0.5	0.1	8
TI-03-V-86	1	-44.3	-46.5	2.2	1.75	0.30	1.03	0.49	1.0	4.9	4.2	17
	2	-46.5	-48.5	2	2.36	0.20	0.46	0.72	2.0	0.7	1.2	6
	3	-48.5	-51	2.5	2.29	0.21	0.56	0.68	2.7	1.1	1.0	5
	4	-51	-53	2	1.77	0.29	0.76	0.59	2.1	3.0	0.3	8
	5	-53	-55.5	2.5	1.80	0.29	0.73	0.60	2.6	3.2	1.0	9
	6	-55.5	-58	2.5	0.92	0.53	1.82	0.28	8.0	8.0	8.8	6
	7	-58	-59.1	1.1	1.80	0.29	0.97	0.51	6.4	3.8	3.9	0
		EL -44.3 to -59.1		D=14.8	1.88	0.27	0.91	0.53	3.4	3.6	3.0	8

Table E-7 **Borings for Borrow Area N**

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-87	1	-46.7	-49	2.3	2.06	0.24	0.84	0.56	7.9	1.4	0.0	3
	2	-49	-51	2	2.22	0.21	0.66	0.63	3.1	2.3	3.7	10
	3	-51	-52.5	1.5	0.40	0.76	3.00	0.12	6.0	3.9	24.8	2
	4	-52.5	-54	0	0.52	0.70	2.25	0.21	8.2	7.9	14.9	2
	5	-54	-55.2	0	-0.33	1.25	3.22	0.11	5.6	3.8	35.8	0
	EL -46.7 to -52.5			D=5.8	1.88	0.27	1.09	0.47	5.8	2.4	7.7	5

Table E-8 <u>Borings for Borrow Area O</u>

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-83B	1	-42.9	-45	2.1	0.33	0.80	3.06	0.12	8.7	8.7	24.6	45
	2	-45	-48	3	0.36	0.78	2.89	0.13	8.0	9.0	23.2	46
	3	-48	-50	0	2.59	0.17	0.61	0.65	13.5	0.5	0.0	3
	4	-50	-51.4	0	2.57	0.17	0.59	0.66	12.8	0.6	1.4	1
	5	-51.4	-55	0	2.68	0.16	0.78	0.58	15.2	0.6	8.5	1
	6	-55	-58	0	2.49	0.18	0.44	0.74	9.1	0.5	0.1	4
	7	-58	-61	0	2.53	0.17	0.45	0.73	12.2	0.2	0.0	1
	8	-61	-62.9	0	2.56	0.17	0.54	0.69	12.8	0.5	7.4	4
		EL -42.9 to -48		D= 5.1	0.33	0.80	2.99	0.13	8.2	8.9	24.6	46

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-85	1	-43.9	-46	2.1	2.10	0.23	0.79	0.58	7.4	3.0	1.4	5
	2	-46	-48.4	2.4	2.05	0.24	0.70	0.61	2.6	1.8	5.1	11
	3	-48.4	-51	0	1.95	0.26	1.15	0.45	9.0	1.6	10.2	1
	4	-51	-53	0	2.54	0.17	0.59	0.67	11.3	1.3	0.0	1
	5	-53	-56	0	2.67	0.16	0.70	0.62	14.5	0.4	0.2	1
	6	-56	-56.9	0	2.47	0.18	0.41	0.75	9.1	0.1	0.0	2
		EL -43.9 to -48.4		D= 4.5	2.07	0.24	0.74	0.60	4.8	2.4	3.5	8

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-322	1	-41.9	-45	3.1	2.51	0.18	0.44	0.74	7.1	0.3	0.4	3
	2	-45	-48	0	2.70	0.15	0.48	0.72	11.2	0.6	0.0	3
	3	-48	-50	0	2.78	0.15	0.62	0.65	14.1	2.0	0.3	5
	4	-50	-52.7	0	3.03	0.12	1.12	0.46	16.9	3.4	1.6	9
	5	-52.7	-54	0	2.90	0.13	0.76	0.59	14.5	1.5	0.2	4
	6	-54	-55.4	0	0.14	0.91	4.27	0.05	9.1	3.1	25.4	3
		EL -41.9 to -45		D=3.1	2.51	0.18	0.44	0.74	7.1	0.3	0.4	3

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-323	1	-40.6	-43.1	2.5	1.58	0.33	1.02	0.49	1.8	4.1	2.9	14
	2	-43.1	-45.5	2.4	2.46	0.18	0.43	0.74	8.0	0.4	0.5	3
	3	-45.5	-48	2.5	2.52	0.17	0.42	0.75	9.3	0.1	0.0	2
	4	-48	-50.5	2.5	2.55	0.17	0.42	0.75	8.6	0.6	0.1	2
	5	-50.5	-53	2.5	2.63	0.16	0.41	0.75	9.7	0.3	0.0	2
	6	-53	-53.7	0	2.73	0.15	0.59	0.66	13.2	1.0	0.3	4
		EL -40.6 to -53		D=12.4	2.46	0.18	0.46	0.73	7.5	1.1	0.7	5

Table E-8 Borings for Borrow Area O Continued

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-324	1	-41.6	-43.4	1.8	-0.79	1.73	3.30	0.10	1.4	8.7	38.2	24
	2	-43.4	-45	1.6	2.27	0.21	0.58	0.67	1.6	1.5	2.2	7
	3	-45	-47	2	2.48	0.18	0.40	0.76	7.1	0.3	0.0	2
	4	-47	-48.6	1.6	2.53	0.17	0.44	0.74	11.6	0.3	0.0	2
		EL -41.6 to -48.6		D=7	1.85	0.28	1.22	0.43	5.4	2.7	10.3	9
TI-03-V-325	1	-42.7	-44.7	2	2.31	0.20	0.59	0.66	4.5	2.7	1.9	9
	2	-44.7	-47	0	2.67	0.16	0.58	0.67	12.8	1.4	0.1	4
	3	-47	-49	0	2.64	0.16	0.57	0.67	11.8	3.2	0.0	8
	4	-49	-51.5	0	2.24	0.21	1.46	0.36	13.5	5.9	1.7	12
	5	-51.5	-53.5	0	2.78	0.15	0.60	0.66	11.4	0.1	0.1	1
	6	-53.5	-55.7	0	2.63	0.16	0.47	0.72	5.0	0.3	0.0	1
		EL -42.7 to -44.7		D=2	2.31	0.20	0.59	0.66	4.5	2.7	1.9	9
TI-03-V-326	1	-42.3	-44	1.7	2.29	0.20	0.56	0.68	3.2	0.9	0.4	6
	2	-44	-45.3	1.3	2.55	0.17	0.47	0.72	9.7	0.1	0.0	0
	3	-45.3	-48	2.7	2.52	0.17	0.44	0.74	7.0	0.1	0.0	0
	4	-48	-50.5	2.5	2.57	0.17	0.41	0.75	4.1	0.0	0.0	0
	5	-50.5	-52.3	1.8	2.56	0.17	0.42	0.75	4.3	0.0	0.0	1
	6	-52.3	-55	2.7	2.59	0.17	0.40	0.76	4.4	0.1	0.0	1
	7	-55	-57.5	0	3.05	0.12	0.54	0.69	10.6	0.0	0.0	1
	8	-57.5	-58.3	0	2.94	0.13	0.47	0.72	8.9	0.0	9.4	1
		EL -42.3 to -55		D=12.7	2.54	0.17	0.43	0.74	5.3	0.2	0.1	1
TI-03-V-327	1	-41	-43	2	1.48	0.36	1.62	0.33	1.9	6.4	6.2	18
	2	-43	-45	2	2.56	0.17	0.52	0.70	9.8	0.5	0.2	4
	3	-45	-47	0	2.81	0.14	0.77	0.58	15.0	0.6	0.2	2
	4	-47	-49.2	0	-0.79	1.72	3.20	0.11	6.6	11.6	42.7	2
	5	-49.2	-51	0	2.40	0.19	2.37	0.19	21.4	5.1	8.7	4
	6	-51	-53.5	0	3.42	0.09	1.03	0.49	25.8	0.9	0.2	2
	7	-53.5	-57	0	3.24	0.11	0.73	0.60	17.9	0.1	0.0	1
	8	-57	-57.5	0	3.21	0.11	0.75	0.59	17.2	0.3	0.0	3
		EL -41 to -45		D=4	2.22	0.22	0.76	0.59	5.9	3.4	3.2	11

Table E-9 Borings for Borrow Area P

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-317	1	-39.5	-40.8	1.3	-0.83	1.78	3.30	0.10	1.8	9.7	38.7	25
	2	-40.8	-44	3.2	1.94	0.26	1.25	0.42	8.3	1.0	0.0	6
	3	-44	-47	0	2.04	0.24	1.61	0.33	13.4	1.0	0.4	5
	4	-47	-50	0	1.99	0.25	1.67	0.31	11.7	3.7	1.3	11
	5	-50	-53	0	1.88	0.27	1.43	0.37	7.7	0.6	0.1	3
	6	-53	-55.5	0	1.88	0.27	1.42	0.37	6.5	0.1	0.0	2
		EL -39.5 to -44		D= 4.5	1.52	0.35	1.75	0.30	6.4	3.5	11.2	11
TI-03-V-318	1	-40.5	-42.5	2	1.99	0.25	0.72	0.61	1.4	1.4	0.6	8
	2	-42.5	-45.3	0	2.96	0.13	1.00	0.50	16.3	0.5	0.1	3
	3	-45.3	-47	0	2.45	0.18	0.52	0.70	6.2	0.1	0.0	1
	4	-47	-49.8	0	2.10	0.23	0.81	0.57	7.7	1.6	0.0	2
	5	-49.8	-50.5	0	4.18	0.06	3.09	0.12	42.8	0.5	0.0	2
	6	-50.5	-53	0	0.68	0.63	-0.17	1.12	2.2	0.5	0.0	1
	7	-53	-54.5	0	1.75	0.30	-0.84	1.80	5.9	0.1	0.0	1
		EL -40.5 to -42.5		D= 2	1.99	0.25	0.72	0.61	1.4	1.4	0.6	8
TI-03-V-320	1	-40.5	-42.4	1.9	-0.56	1.47	2.84	0.14	1.3	13.0	32.0	21
	2	-42.4	-45	2.6	2.34	0.20	0.49	0.71	7.7	0.9	0.0	4
	3	-45	-48	3	2.46	0.18	0.38	0.77	5.2	0.1	0.0	2
	4	-48	-51	3	2.52	0.17	0.41	0.75	8.0	0.1	0.3	2
	5	-51	-54	3	2.55	0.17	0.39	0.76	5.5	0.1	0.0	1
	6	-54	-54.5	0.5	2.59	0.17	0.40	0.76	8.2	0.9	0.0	3
		EL -40.5 to -51		D=10.5	2.23	0.21	0.66	0.63	5.9	2.0	5.9	5

Table E-10 Borings for Borrow Area Q

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-161	1	-35.4	-37.5	2.1	2.21	0.22	0.57	0.67	1.8	0.7	0.3	8
	2	-37.5	-39	1.5	2.00	0.25	1.00	0.50	6.1	3.4	6.9	11
	3	-39	-39.6	0.6	2.46	0.18	0.41	0.75	6.8	0.2	0.0	3
		EL -35.4 to -39.6		D= 4.2	2.23	0.21	0.61	0.65	4.1	1.6	2.6	8
TI-03-V-162	1	-35.2	-37.5	2.3	1.60	0.33	1.58	0.33	4.0	6.0	5.1	19
	2	-37.5	-39.7	2.2	2.76	0.15	0.57	0.67	10.6	1.5	0.3	8
	3	-39.7	-41.2	1.5	2.41	0.19	0.40	0.76	7.0	0.2	0.0	1
		EL -35.2 to -41.2		D=6	2.35	0.20	0.70	0.62	7.2	2.9	2.1	10

Table E-11 Borings for Borrow Area S

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-46	1	-44.7	-47	2.3	0.17	0.89	2.09	0.23	3.3	15.6	12.7	47
	2	-47	-48	0	2.01	0.25	2.22	0.21	16.7	6.5	0.4	8
	3	-48	-50	0	-0.13	1.10	2.42	0.19	9.2	22.1	18.1	3
	4	-50	-53	0	-1.41	2.66	2.95	0.13	6.1	21.0	39.5	1
		EL -44.7 to -47		D= 2.3	0.17	0.89	2.09	0.23	3.3	15.6	12.7	47

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt	% Granular	% Gravel	% Shell
TI-03-V-47	1	-44.5	-45.5	1	1.98	0.25	0.93	0.53	4.0	5.0	0.2	22
	2	-45.5	-47.3	1.8	-0.02	1.01	2.50	0.18	6.8	22.0	17.2	58
	3	-47.3	-50	0	0.67	0.63	3.18	0.11	16.4	23.7	12.6	14
	4	-50	-52	0	-0.20	1.15	2.51	0.18	8.3	21.7	19.4	2
	5	-52	-54	0	0.19	0.87	2.50	0.18	12.0	19.6	16.4	1
	6	-54	-55.7	0	-0.99	1.98	2.56	0.17	5.8	22.4	34.5	1
		EL -44.5 to -47.3		D=2.8	0.82	0.57	2.28	0.21	5.8	16.0	11.1	45

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt	% Granular	% Gravel	% Shell
TI-03-V-48	1	-44.2	-46.4	2.2	1.63	0.32	1.12	0.46	3.9	6.2	2.0	18
	2	-46.4	-48.2	0	1.93	0.26	2.82	0.14	17.3	10.6	5.2	27
	3	-48.2	-50	0	0.36	0.78	2.55	0.17	10.8	17.3	17.0	1
	4	-50	-52	0	-0.01	1.01	2.69	0.15	13.5	24.1	18.5	0
	5	-52	-54	0	0.15	0.90	2.39	0.19	10.3	21.9	14.7	1
	6	-54	-55.2	0	0.41	0.75	2.48	0.18	11.3	19.3	14.9	1
		EL -44.2 to -46.4		D=2.2	1.63	0.32	1.12	0.46	3.9	6.2	2.0	18

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt	% Granular	% Gravel	% Shell
TI-03-V-49	1	-43.8	-46.1	2.3	2.22	0.21	0.53	0.69	1.3	0.9	0.1	8
	2	-46.1	-47.7	0	2.68	0.16	1.05	0.48	14.3	1.3	1.4	8
	3	-47.7	-49.3	0	3.52	0.09	1.26	0.42	33.1	0.1	0.0	1
	4	-49.3	-51.5	0	2.63	0.16	0.64	0.64	7.9	0.2	0.0	2
	5	-51.5	-54.1	0	1.50	0.35	1.67	0.31	11.7	5.4	7.6	2
	6	-54.1	-55	0	-0.13	1.09	2.74	0.15	7.6	14.7	23.9	1
		EL -43.8 to -46.1		D=2.3	2.22	0.21	0.53	0.69	1.3	0.9	0.1	8

Table E-11 **Borings for Borrow Area S Continued**

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-51	1	-44.1	-46.7	2.6	2.01	0.25	0.67	0.63	1.8	2.8	0.5	16
	2	-46.7	-50	0	3.57	0.08	2.30	0.20	27.2	3.6	3.0	12
	3	-50	-52	0	2.25	0.21	0.70	0.61	13.3	3.0	0.7	2
	4	-52	-54	0	2.28	0.21	0.69	0.62	13.1	1.2	0.2	2
	5	-54	-56	0	1.44	0.37	1.78	0.29	11.7	4.5	10.2	2
	6	-56	-57.6	0	-0.66	1.58	3.46	0.09	7.6	9.7	34.5	1
		EL -44.1 to -46.7		D=2.6	2.01	0.25	0.67	0.63	1.8	2.8	0.5	16
TI-03-V-52	1	-44.2	-46	1.8	1.96	0.26	0.58	0.67	1.4	1.0	0.9	9
	2	-46	-47.7	1.7	2.40	0.19	0.41	0.75	2.1	1.0	1.7	6
		EL -44.2 to -47.7		D=3.5	2.18	0.22	0.56	0.68	1.8	1.0	1.3	8
TI-03-V-53	1	-44.8	-46.3	1.5	2.31	0.20	0.43	0.74	1.2	0.1	0.0	6
	2	-46.3	-47.5	1.2	1.30	0.41	1.98	0.25	11.2	12.4	1.7	32
		EL -44.8 to -47.5		D=2.7	1.98	0.25	0.93	0.52	5.6	5.6	1.7	18

Table E-12 Borings for Borrow Area T

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-14	1	-37.2	-39.5	2.3	2.18	0.22	0.54	0.69	1.4	2.0	0.5	8
	2	-39.5	-40.4	0.9	1.12	0.46	1.50	0.35	1.4	4.0	10.5	24
		EL -37.2 to -40.4		D= 3.2	1.97	0.26	0.74	0.60	1.4	2.6	3.3	13
TI-03-V-17	1	-40.6	-43	2.4	1.97	0.25	0.66	0.63	1.2	1.5	0.6	14
	2	-43	-45	2	2.16	0.22	0.54	0.69	2.6	0.6	0.4	7
	3	-45	-47	2	1.40	0.38	1.46	0.36	2.9	4.6	7.5	25
	4	-47	-49.2	2.2	1.78	0.29	0.82	0.57	2.6	2.5	75.3	21
		EL -40.6 to -49.2		D=8.6	1.91	0.27	0.78	0.58	2.3	2.3	2.9	17
TI-03-V-22	1	-41.6	-42.1	0.5	1.29	0.41	1.73	0.30	4.8	9.6	5.0	9
	2	-42.1	-43.8	1.7	2.38	0.19	0.53	0.69	10.5	0.0	0.0	2
		EL -41.6 to -43.8		D=2.2	2.26	0.21	0.62	0.65	9.2	2.2	1.1	4
TI-03-V-23	1	-41.4	-43	1.6	1.80	0.29	0.65	0.64	1.6	0.5	0.0	10
	2	-43	-45	2	0.14	0.91	2.55	0.17	2.1	12.7	21.5	44
	3	-45	-45.9	0.9	2.51	0.18	0.42	0.75	4.9	0.5	0.3	4
	4	-45.9	-48.2	0	0.16	0.90	3.55	0.09	15.3	12.0	31.1	1
		EL -41.4 to -45.9		D=4.5	1.18	0.44	1.74	0.30	2.5	5.9	9.6	24
TI-03-V-27	1	-42	-43.9	1.9	1.77	0.29	0.69	0.62	1.1	0.8	0.1	19
	2	-43.9	-44.4	0.5	1.79	0.29	0.75	0.60	1.3	2.0	2.2	19
		EL -42.7 to -44.7		D=2.4	1.78	0.29	0.70	0.62	1.2	1.1	0.6	19

Table E-13 Borings for Borrow Area A

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-124	1	-38.5	-40.5	2	1.72	0.30	1.59	0.33	9.0	8.5	2.1	22
	2	-40.5	-42.5	0	2.37	0.19	0.54	0.69	18.2	3.2	1.0	11
	3	-42.5	-45	0	2.79	0.14	0.42	0.75	5.6	0.1	0.0	3
	4	-45	-48	0	2.84	0.14	0.58	0.67	12.7	0.0	0.0	1
	5	-48	-51	0	2.73	0.15	0.67	0.63	13.9	0.0	0.0	1
	6	-51	-53.5	0	2.61	0.16	0.47	0.72	11.2	0.0	0.0	1
		EL -38.5 to -40.5		D= 2	1.72	0.30	1.59	0.33	9.0	8.5	2.1	22
TI-03-V-125	1	-38.9	-40.9	2	2.31	0.20	0.98	0.51	8.4	4.5	2.6	17
	2	-40.9	-43	0	2.71	0.15	0.58	0.67	11.3	2.8	0.3	9
	3	-43	-46	0	2.94	0.13	0.42	0.75	11.8	0.1	0.0	1
	4	-46	-48	0	2.93	0.13	0.44	0.74	11.7	0.0	0.0	1
	5	-48	-50.5	0	2.95	0.13	0.55	0.68	13.2	0.0	0.0	1
	6	-50.5	-51	0	2.88	0.14	0.67	0.63	13.4	0.0	0.0	1
		EL -38.9 to -40.9		D=2	2.31	0.20	0.98	0.51	8.4	4.5	2.6	17
TI-03-V-126	1	-38.7	-41	2.3	1.00	0.50	2.20	0.22	8.7	14.9	6.5	43
	2	-41	-43.5	2.5	2.77	0.15	0.38	0.77	6.0	0.5	0.1	3
	3	-43.5	-45.5	0	3.06	0.12	0.64	0.64	16.4	1.1	0.0	2
	4	-45.5	-47.5	0	2.75	0.15	0.57	0.67	12.7	0.4	0.0	2
	5	-47.5	-49.2	0	3.28	0.10	1.32	0.40	21.7	1.2	0.7	1
	6	-49.2	-49.7	0	2.81	0.14	0.61	0.66	14.2	0.2	0.1	2
		EL -38.7 to -43.5		D=4.8	1.76	0.30	1.79	0.29	7.3	7.4	3.2	22
TI-03-V-127	1	-39.8	-42.3	2.5	1.41	0.38	1.91	0.27	3.8	6.6	8.5	28
	2	-42.3	-44	1.7	2.86	0.14	0.36	0.78	6.9	0.1	0.0	1
	3	-44	-44.7	0.7	2.90	0.13	0.36	0.78	6.2	0.2	0.0	1
		EL -39.8 to -44.7		D=4.9	2.19	0.22	1.11	0.46	5.2	3.4	4.3	15

Table E-13 Borings for Borrow Area A Continued

Boring Number	Layer Number	Layer Depth (ft)		Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
		Top	Bottom									
TI-03-V-129	1	-40.9	-42.5	1.6	1.48	0.36	1.25	0.42	1.2	5.5	0.9	24
	2	-42.5	-43.4	0.9	2.41	0.19	0.54	0.69	1.8	2.1	0.3	9
	3	-43.4	-44.3	0.9	ND	ND	ND	ND	37.3	1.8	0.0	7
	4	-44.3	-47.6	3.3	1.59	0.33	1.16	0.45	7.4	2.7	0.5	6
	5	-47.6	-49.2	1.6	ND	ND	ND	ND	70.7	0.1	0.0	1
		EL -40.9 to -43.4		D=2.5	1.84	0.28	1.09	0.47	1.4	4.2	0.7	19
TI-03-V-130	1	-42.6	-45.1	2.5	2.62	0.16	0.51	0.70	8.0	2.3	0.1	7
	2	-45.1	-47	1.9	2.82	0.14	0.32	0.80	4.9	0.2	0.0	2
	3	-47	-49	2	2.82	0.14	0.29	0.82	3.6	0.1	0.0	1
	4	-49	-50.9	1.9	2.65	0.16	0.44	0.74	3.8	0.0	0.0	1
		EL -42.6 to -50.9		D=8.3	2.71	0.15	0.42	0.75	5.3	0.7	0.0	3
TI-03-V-182	1	-44.7	-46	1.3	2.30	0.20	0.63	0.65	2.5	1.8	0.5	7
	2	-46	-47	1	1.88	0.27	1.26	0.42	2.2	6.4	2.1	11
	3	-47	-49	2	2.90	0.13	0.44	0.74	11.2	0.1	0.0	1
	4	-49	-52.3	3.3	2.93	0.13	0.42	0.75	12.2	0.1	0.0	0
		EL -44.7 to -49		D=4.3	2.55	0.17	0.49	0.71	6.5	2.1	0.6	5
TI-03-V-187	1	-42.5	-44.5	2	2.40	0.19	0.65	0.64	2.9	3.5	1.3	11
	2	-44.5	-46.5	2	2.81	0.14	0.55	0.68	9.1	1.9	0.3	7
	3	-46.5	-49	2.5	2.92	0.13	0.40	0.76	8.9	0.1	0.0	1
	4	-49	-52	3	2.92	0.13	0.42	0.75	9.4	0.0	0.0	1
	5	-52	-54	2	2.81	0.14	0.56	0.68	10.6	0.0	0.0	1
	6	-54	-55.5	1.5	3.37	0.10	1.27	0.41	20.4	0.0	0.0	1
		EL -42.5 to -46.5		D=4	2.63	0.16	0.56	0.68	6.0	2.7	0.8	9

Table E-13 Borings for Borrow Area A Continued

Boring Number	Layer Number	Layer Depth (ft) Top	Layer Depth (ft) Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-188	1	-44.2	-47.8	3.6	1.74	0.30	1.51	0.35	3.2	5.2	6.2	19
	2	-47.8	-50	2.2	2.97	0.13	0.46	0.73	12.2	0.2	0.0	2
	3	-50	-52	2	3.07	0.12	0.52	0.70	11.6	0.0	0.0	0
	4	-52	-54.2	2.2	2.93	0.13	0.48	0.72	12.0	0.1	0.0	1
		EL -44.2 to -52		D=7.8	2.69	0.15	0.65	0.64	7.9	2.5	2.9	9
TI-03-V-189	1	-45.5	-47.5	2	2.36	0.20	0.60	0.66	2.9	1.8	0.9	8
	2	-47.5	-51	3.5	2.06	0.24	1.16	0.45	7.6	5.6	3.8	16
	3	-51	-54.8	3.8	2.81	0.14	0.60	0.66	11.6	1.8	1.1	8
	4	-54.8	-57	2.2	2.91	0.13	0.46	0.73	10.5	1.5	0.7	5
	5	-57	-59	2	3.04	0.12	0.55	0.68	12.1	0.1	0.0	3
	6	-59	-59.5	0.5	2.92	0.13	0.47	0.72	11.8	0.1	0.0	2
		EL -45.5 to -54.8		D=9.3	2.46	0.18	0.77	0.59	8.2	3.3	2.1	11
TI-03-V-197	1	-45.5	-47	1.5	2.23	0.21	0.64	0.64	1.6	2.1	3.2	8
	2	-47	-49.5	2.5	2.88	0.14	0.43	0.74	10.1	0.5	0.6	3
	3	-49.5	-52	2.5	3.35	0.10	0.77	0.59	26.7	0.2	0.1	1
	4	-52	-52.9	0.9	ND	ND	ND	ND	73.5	0.0	0.0	0
	5	-52.9	-55	2.1	3.61	0.08	1.03	0.49	40.5	0.0	0.0	1
	6	-55	-56.7	1.7	3.71	0.08	1.18	0.44	42.0	0.1	0.0	1
	7	-56.7	-57.5	0.8	ND	ND	ND	ND	72.4	0.1	0.0	0
		EL -45.5 to -49.5		D=4	2.61	0.16	0.51	0.70	6.9	1.1	1.6	5
TI-03-V-202	1	-46.3	-48	1.7	2.24	0.21	0.75	0.59	1.8	3.5	1.5	9
	2	-48	-50	2	2.70	0.15	0.79	0.58	12.6	2.8	0.7	9
	3	-50	-52	2	2.99	0.13	1.09	0.47	18.3	2.4	0.6	10
	4	-52	-53.9	1.9	2.92	0.13	0.69	0.62	15.3	2.3	0.8	9
		EL -46.3 to -50		D=3.7	2.44	0.18	0.77	0.59	7.6	3.2	1.1	9

Table E-13 Borings for Borrow Area A Continued

Boring Number	Layer Number	Layer Depth (ft)		Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
		Top	Bottom									
TI-03-V-203	1	-43.4	-45.5	2.1	0.93	0.52	2.03	0.25	2.3	9.9	9.4	25
	2	-45.5	-46.6	1.1	2.28	0.21	0.64	0.64	1.8	2.1	3.1	10
		EL -43.4 to -46.6		D=3.2	1.34	0.39	1.78	0.29	2.1	7.2	7.2	20
TI-03-V-208	1	-49	-51	2	2.61	0.16	0.42	0.75	4.6	1.4	0.4	6
	2	-51	-52.2	1.2	2.88	0.14	0.41	0.75	9.6	0.8	0.1	3
		EL -49 to -52.2		D=3.2	2.70	0.15	0.44	0.74	6.5	1.2	0.3	5
TI-03-V-216	1	-48.2	-49	0.8	1.15	0.45	2.12	0.23	1.9	10.4	9.3	23
	2	-49	-50.3	1.3	1.75	0.30	1.94	0.26	12.3	7.9	4.6	18
		EL -48.2 to -50.3		D=2.1	1.45	0.36	1.95	0.26	8.3	8.9	6.4	20

Table E-14 <u>Borings for Borrow Area B</u>

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-132	1	-42.2	-43.8	1.6	0.58	0.67	2.04	0.24	1.5	12.3	9.4	44
	2	-43.8	-46	2.2	2.64	0.16	0.44	0.74	5.3	0.9	0.1	5
	3	-46	-47.6	1.6	2.86	0.14	0.37	0.77	6.7	0.1	0.0	2
		EL -42.2 to -47.6		D= 5.4	2.09	0.23	1.16	0.45	4.6	4.0	2.8	16

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-205	1	-43.2	-45.2	2	2.39	0.19	0.56	0.68	2.2	0.9	0.1	6
	2	-45.2	-47.2	0	ND	ND	ND	ND	64.2	0.0	0.0	0
	3	-47.2	-50	0	3.73	0.08	1.02	0.49	36.3	0.1	0.0	1
	4	-50	-53	0	3.74	0.08	1.09	0.47	37.8	0.0	0.0	1
	5	-53	-55.2	0	3.32	0.10	0.84	0.56	21.5	0.0	0.0	1
		EL -43.2 to -45.2		D=2	2.39	0.19	0.56	0.68	2.2	0.9	0.1	6

Table E-15 Borings for Borrow Area C

Boring Number	Layer Number	Layer Depth (ft)		Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
		Top	Bottom									
TI-03-V-174	**1**	**-45.5**	**-47.8**	**2.3**	**2.43**	**0.18**	**0.53**	**0.69**	**2.4**	**2.5**	**2.1**	**9**
	2	-47.8	-49.5	0	ND	ND	ND	ND	68.4	0.1	0.0	3
	3	-49.5	-50.5	0	ND	ND	ND	ND	80.8	0.6	0.4	3
	4	-50.5	-51.3	0	3.53	0.09	1.27	0.41	24.4	1.0	0.3	2
		EL -45.5 to -47.8		**D= 2.3**	**2.43**	**0.18**	**0.53**	**0.69**	**2.4**	**2.5**	**2.1**	**9**
TI-03-V-178	**1**	**-46.3**	**-48.5**	**2.2**	**2.58**	**0.17**	**0.53**	**0.69**	**7.0**	**0.9**	**4.9**	**9**
	2	-48.5	-50.5	0	2.95	0.13	0.43	0.74	9.5	0.2	0.3	2
	3	-50.5	-52	0	2.52	0.17	0.81	0.57	8.5	1.8	5.2	11
	4	-52	-54.5	0	2.59	0.17	0.49	0.71	7.2	0.0	0.0	2
	5	-54.5	-57	0	2.50	0.18	0.44	0.74	3.6	0.1	0.0	3
	6	-57	-60	0	2.06	0.24	0.87	0.55	3.6	0.8	0.1	9
	7	-60	-62.5	0	2.01	0.25	0.87	0.55	2.1	0.4	0.0	2
	8	-62.5	-63.3	0	2.69	0.15	0.31	0.81	3.0	0.0	0.0	1
		EL -46.3 to -48.5		**D=2.2**	**2.58**	**0.17**	**0.53**	**0.69**	**7.0**	**0.9**	**4.9**	**9**
TI-03-V-185	**1**	**-46.5**	**-48.5**	**2**	**2.38**	**0.19**	**0.53**	**0.69**	**1.2**	**1.4**	**0.5**	**5**
	2	**-48.5**	**-51**	**2.5**	**2.73**	**0.15**	**0.63**	**0.65**	**11.7**	**1.2**	**1.2**	**8**
	3	-51	-53	0	3.12	0.11	0.68	0.62	15.1	0.8	0.5	8
	4	-53	-55	0	ND	ND	ND	ND	49.9	0.3	0.2	1
	5	-55	-58	0	ND	ND	ND	ND	82.3	0.0	0.0	0
	6	-58	-61	3	ND	ND	ND	ND	84.5	0.0	0.0	0
	7	-61	-64.3	0	3.32	0.10	0.81	0.57	22.0	0.1	0.0	1
	8	-64.3	-64.8	0	3.06	0.12	0.72	0.61	14.9	0.0	0.0	1
		EL -46.5 to -51		**D=4.5**	**2.54**	**0.17**	**0.49**	**0.71**	**7.0**	**1.3**	**0.9**	**7**

Table E-15 Borings for Borrow Area C Continued

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-186	1	-47.7	-49.5	1.8	2.42	0.19	0.49	0.71	2.6	1.5	1.1	7
	2	-49.5	-51	1.5	2.48	0.18	0.43	0.74	4.5	0.9	4.0	7
	3	-51	-53.9	2.9	2.73	0.15	0.51	0.70	7.9	0.2	0.0	2
	4	-53.9	-56	2.1	ND	ND	ND	ND	54.1	0.2	0.0	2
	5	-56	-57	1	ND	ND	ND	ND	65.6	0.1	0.0	0
	6	-57	-60	3	3.28	0.10	0.84	0.56	21.8	0.2	0.1	2
	7	-60	-63	3	2.93	0.13	0.45	0.73	10.8	0.1	0.0	2
	8	-63	-65.5	2.5	3.18	0.11	0.76	0.59	16.8	0.1	0.0	1
		EL -47.7 to -51		D=3.3	2.46	0.18	0.44	0.73	3.4	1.2	2.4	7
TI-03-V-192	1	-47	-49	2	2.10	0.23	0.69	0.62	1.5	1.2	0.1	7
	2	-49	-50	1	ND	ND	ND	ND	35.1	1.2	0.0	1
		EL -47 to -49		D=2	2.10	0.23	0.69	0.62	1.5	1.2	0.1	7
TI-03-V-198	1	-46.5	-48.5	2	1.35	0.39	1.75	0.30	1.5	5.3	9.8	20
	2	-48.5	-49.5	1	2.33	0.20	0.56	0.68	2.3	1.7	1.5	7
	3	-49.5	-50.5	1	3.29	0.10	1.05	0.48	23.9	0.1	0.0	1
	4	-50.5	-52.5	2	2.43	0.18	0.60	0.66	6.1	0.0	0.0	0
	5	-52.5	-54.5	2	3.05	0.12	0.48	0.72	7.8	0.0	0.0	0
		EL -46.5 to -49.5		D=3	1.84	0.28	1.14	0.45	1.7	4.1	7.1	16
TI-03-V-199	1	-46.6	-48.8	2.2	2.14	0.23	0.70	0.62	1.4	0.7	0.5	7
	2	-48.8	-51.1	2.3	3.11	0.12	0.68	0.63	14.2	0.1	0.0	2
	3	-51.1	-51.6	0.5	2.97	0.13	0.73	0.60	13.8	0.1	0.0	2
		EL -46.6 to -48.8		D=2.2	2.14	0.23	0.70	0.62	1.4	0.7	0.5	7

Table E-16 Borings for Borrow Area D

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-223	1	-43.5	-45	1.5	2.12	0.23	0.63	0.65	0.9	1.3	1.1	8
	2	-45	-46.5	1.5	1.85	0.28	0.90	0.54	1.3	4.4	4.5	16
	3	-46.5	-47.2	0	3.00	0.13	1.15	0.45	19.4	3.3	1.1	8
		EL -43.5 to -46.5		D= 3	2.00	0.25	0.75	0.59	1.1	2.9	2.8	12
TI-03-V-224	1	-46.4	-48.4	2	2.23	0.21	0.54	0.69	1.5	2.1	1.4	7
	2	-48.4	-50.5	0	3.63	0.08	1.46	0.36	32.5	0.5	0.0	2
	3	-50.5	-52.6	0	3.38	0.10	0.86	0.55	28.0	0.2	0.0	1
		EL -46.4 to -48.4		D=2	2.23	0.21	0.54	0.69	1.5	2.1	1.4	7
TI-03-V-228	1	-46.9	-47.9	1	2.10	0.23	0.68	0.63	1.6	2.0	0.5	6
	2	-47.9	-50.6	2.7	1.29	0.41	2.08	0.24	7.4	12.8	5.2	18
	3	-50.6	-52.5	1.9	2.93	0.13	0.44	0.73	11.3	0.9	0.1	3
	4	-52.5	-53.6	1.1	2.92	0.13	0.46	0.73	11.0	2.2	1.7	5
		EL -46.9 to -53.6		D=6.7	2.16	0.22	1.23	0.43	8.2	6.1	2.5	10

Table E-17 Borings for Borrow Area E

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-240	1	-50	-52	2	1.78	0.29	0.74	0.60	1.0	1.7	3.5	9
	2	-52	-52.8	0.8	2.56	0.17	0.42	0.75	5.7	0.6	0.2	3
		EL -50 to -52.8		D= 2.8	2.00	0.25	0.82	0.57	2.3	1.4	2.5	7

Boring Number	Layer Number	Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-241	1	-49	-51.2	2.2	2.01	0.25	0.50	0.71	0.8	0.5	0.5	4
	2	-51.2	-53	1.8	2.55	0.17	0.45	0.73	7.6	0.7	0.1	3
	3	-53	-54	0	3.87	0.07	1.27	0.42	42.6	0.1	0.0	1
	4	-54	-56.1	0	3.62	0.08	1.39	0.38	36.0	0.1	0.0	1
		EL -49 to -53		D=4	2.25	0.21	0.61	0.66	3.9	0.6	0.3	4

Table E-18 <u>Borings for Borrow Area F</u>

Boring Number	Layer Number	Layer Depth (ft) Top	Bottom	Layer Thickness (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-245	1	-47.2	-48.5	1.3	0.50	0.71	1.47	0.36	1.8	9.6	6.6	18
	2	-48.5	-49.7	1.2	1.55	0.34	1.37	0.39	1.4	4.5	8.0	18
		EL -47.2 to -49.7		D= 2.5	0.96	0.51	1.64	0.32	1.6	7.2	7.3	18
TI-03-V-369	1	-48	-49	1	1.73	0.30	1.25	0.42	7.3	3.6	0.3	2
	2	-49	-51	2	0.82	0.56	2.34	0.20	4.7	8.4	14.1	3
	3	-51	-53	2	-0.08	1.06	2.64	0.16	6.2	13.4	20.6	1
		EL -48 to -51		D=3	1.20	0.44	1.90	0.27	5.6	6.8	9.5	2

Table E-19 Composite Characteristics for Borrow Area G

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-254	5.0	2.09	0.23	0.90	0.54	7.6	3.5	3.8	5
TI-03-V-256	2.0	2.09	0.23	0.62	0.65	1.1	0.8	2.0	7
TI-03-V-257	3.0	2.04	0.24	0.97	0.51	3.9	2.9	7.2	14
TI-03-V-258	2.8	0.89	0.54	2.48	0.18	2.8	6.9	15.7	28
TI-03-V-275	5.5	2.58	0.17	0.43	0.74	6.3	0.4	1.2	4

Borrow Area G Composite Data

Mean	**2.0**
Mean (mm)	**0.24**
Std Dev (phi)	**1.0**
Std Dev (mm)	**0.51**
% Silt	**5.2**
% Granular	**2.7**
% Gravel	**5.2**
% Shell	**10**

Table E-20 Composite Characteristics for Borrow Area H

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-260	2.2	2.07	0.24	0.87	0.55	3.6	2.2	4.5	11
TI-03-V-273	4.8	2.27	0.21	0.55	0.68	2.1	1.3	0.9	5

Borrow Area H Composite Data

Mean	**2.21**
Mean (mm)	**0.22**
Std Dev (phi)	**0.65**
Std Dev (mm)	**0.64**
% Silt	**2.6**
% Granular	**1.6**
% Gravel	**2.0**
% Shell	**7**

Table E-21 Composite Characteristics for Borrow Area J

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-98	2.8	2.13	0.23	0.73	0.60	5.2	1.3	0.5	11
TI-03-V-99	8.3	2.45	0.18	0.44	0.74	9.5	1.4	0.2	6
TI-03-V-102	3.0	1.86	0.27	1.05	0.48	2.3	4.5	1.3	16
TI-03-V-103	2.6	2.29	0.20	0.58	0.67	2.8	1.6	0.2	10
TI-03-V-270A	2.0	2.00	0.25	0.81	0.57	1.5	3.0	1.1	9
TI-03-V-281	3.4	2.02	0.25	0.72	0.61	1.2	2.5	1.0	10
TI-03-V-283	3.2	1.87	0.27	0.88	0.54	2.1	3.7	1.8	9
TI-03-V-286	4.0	1.85	0.28	1.15	0.45	2.6	1.8	3.3	14

Borrow Area J Composite Data

Mean	**2.12**
Mean (mm)	**0.23**
Std Dev (phi)	**0.75**
Std Dev (mm)	**0.60**
% Silt	**4.5**
% Granular	**2.3**
% Gravel	**1.1**
% Shell	**10**

Table E-22 **Composite Characteristics for Borrow Area L**

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-91	3.5	1.61	0.33	1.69	0.31	7.1	4.4	9.6	19
TI-03-V-93	2.3	2.15	0.23	0.83	0.56	8.5	3.8	0.8	15
TI-03-V-95	13.8	2.50	0.18	0.42	0.75	8.4	0.9	0.2	6
TI-03-V-341	4.3	2.12	0.23	0.88	0.54	6.3	2.5	0.7	6
TI-03-V-342	2.0	1.89	0.27	1.04	0.49	3.8	5.6	2.8	15
TI-03-V-343	5.0	2.37	0.19	0.50	0.71	3.3	1.0	0.4	3
TI-03-V-344	2.3	0.81	0.57	2.23	0.21	1.6	7.0	13.8	22
TI-03-V-345	3.0	1.65	0.32	1.01	0.50	1.8	2.8	2.1	15
TI-03-V-346	3.0	1.93	0.26	1.09	0.47	7.6	3.4	4.9	13
TI-03-V-351	2.8	1.31	0.40	2.13	0.23	7.3	7.4	10.5	16

Borrow Area L Composite Data

Mean	**2.05**
Mean (mm)	**0.24**
Std Dev (phi)	**0.94**
Std Dev (mm)	**0.52**
% Silt	**6.3**
% Granular	**2.8**
% Gravel	**3.1**
% Shell	**10**

Table E-23 Composite Characteristics for Borrow Area N

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-63	3.0	2.08	0.24	0.63	0.65	1.2	2.2	4.9	14
TI-03-V-65	5.5	2.37	0.19	0.43	0.74	1.5	0.5	0.6	7
TI-03-V-68	6.0	1.71	0.31	1.20	0.44	4.6	3.4	2.7	3
TI-03-V-69	3.7	1.31	0.40	1.71	0.31	1.1	5.7	8.8	24
TI-03-V-70	5.0	1.33	0.40	1.46	0.36	6.3	4.4	8.4	14
TI-03-V-72	2.8	0.54	0.69	1.64	0.32	1.1	6.9	10.9	19
TI-03-V-74	5.5	2.20	0.22	0.67	0.63	3.3	3.4	3.5	10
TI-03-V-77	2.3	2.23	0.21	0.57	0.67	1.4	1.5	0.9	7
TI-03-V-78	4.0	2.38	0.19	0.65	0.64	4.8	3.5	4.1	9
TI-03-V-79	2.3	2.03	0.24	0.60	0.66	1.6	0.5	0.1	8
TI-03-V-86	14.8	1.88	0.27	0.91	0.53	3.4	3.6	3.0	8
TI-03-V-87	5.8	1.88	0.27	1.09	0.47	5.8	2.4	7.7	5

Borrow Area N Composite Data

Mean	**1.86**
Mean (mm)	**0.28**
Std Dev (phi)	**0.96**
Std Dev (mm)	**0.51**
% Silt	**3.6**
% Granular	**3.2**
% Gravel	**4.8**
% Shell	**9**

Table E-24 Composite Characteristics for Borrow Area O

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-83B	5.1	0.33	0.80	2.99	0.13	8.2	8.9	24.6	46
TI-03-V-85	4.5	2.07	0.24	0.74	0.60	4.8	2.4	3.5	8
TI-03-V-322	3.1	2.51	0.18	0.44	0.74	7.1	0.3	0.4	3
TI-03-V-323	12.4	2.46	0.18	0.46	0.73	7.5	1.1	0.7	5
TI-03-V-324	7.0	1.85	0.28	1.22	0.43	5.4	2.7	10.3	9
TI-03-V-325	2.0	2.31	0.20	0.59	0.66	4.5	2.7	1.9	9
TI-03-V-326	12.7	2.54	0.17	0.43	0.74	5.3	0.2	0.1	1
TI-03-V-327	4.0	2.22	0.22	0.76	0.59	5.9	3.4	3.2	11

Borrow Area O Composite Data

Mean	**2.12**
Mean (mm)	**0.23**
Std Dev (phi)	**0.86**
Std Dev (mm)	**0.55**
% Silt	**6.2**
% Granular	**2.0**
% Gravel	**4.7**
% Shell	**9**

Table E-25 Composite Characteristics for Borrow Area P

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-317	4.5	1.52	0.35	1.75	0.30	6.4	3.5	11.2	11
TI-03-V-318	2.0	1.99	0.25	0.72	0.61	1.4	1.4	0.6	8
TI-03-V-320	10.5	2.23	0.21	0.66	0.63	5.9	2.0	5.9	5

Borrow Area P Composite Data

Mean	**2.01**
Mean (mm)	**0.25**
Std Dev (phi)	**0.96**
Std Dev (mm)	**0.52**
% Silt	**5.5**
% Granular	**2.4**
% Gravel	**6.6**
% Shell	**7**

Table E-26 Composite Characteristics for Borrow Area Q

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-161	4.2	2.23	0.21	0.61	0.65	4.1	1.6	2.6	8
TI-03-V-162	6.0	2.35	0.20	0.70	0.62	7.2	2.9	2.1	10

Borrow Area Q Composite Data

Mean	**2.30**
Mean (mm)	**0.20**
Std Dev (phi)	**0.66**
Std Dev (mm)	**0.63**
% Silt	**5.9**
% Granular	**2.4**
% Gravel	**2.3**
% Shell	**10**

Table E-27 Composite Characteristics for Borrow Area S

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-46	2.3	0.17	0.89	2.09	0.23	3.3	15.6	12.7	47
TI-03-V-47	2.8	0.82	0.57	2.28	0.21	5.8	16.0	11.1	45
TI-03-V-48	2.2	1.63	0.32	1.12	0.46	3.9	6.2	2.0	18
TI-03-V-49	2.3	2.34	0.20	0.30	0.81	1.3	0.9	0.1	8
TI-03-V-51	2.6	2.01	0.25	0.67	0.63	1.8	2.8	0.5	16
TI-03-V-52	3.5	2.18	0.22	0.56	0.68	1.8	1.0	1.3	8
TI-03-V-53	2.7	1.98	0.25	0.93	0.52	5.6	5.6	1.7	18

Borrow Area S Composite Data

Mean	**1.62**
Mean (mm)	**0.32**
Std Dev (phi)	**1.12**
Std Dev (mm)	**0.46**
% Silt	**3.3**
% Granular	**6.6**
% Gravel	**4.1**
% Shell	**21**

Table E-28 Composite Characteristics for Borrow Area T

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-14	3.2	1.97	0.26	0.74	0.60	1.4	2.6	3.3	13
TI-03-V-17	8.6	1.91	0.27	0.78	0.58	2.3	2.3	2.9	17
TI-03-V-22	2.2	2.26	0.21	0.62	0.65	9.2	2.2	1.1	4
TI-03-V-23	4.5	1.18	0.44	1.74	0.30	2.5	5.9	9.6	24
TI-03-V-27	2.4	1.78	0.29	0.70	0.62	1.2	1.1	0.6	19

Borrow Area T Composite Data

Mean	**1.78**
Mean (mm)	**0.29**
Std Dev (phi)	**0.95**
Std Dev (mm)	**0.52**
% Silt	**2.8**
% Granular	**3.0**
% Gravel	**3.9**
% Shell	**16.5**

Table E-29 Composite Characteristics for Borrow Area A

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-124	2.0	1.72	0.30	1.59	0.33	9.0	8.5	2.1	22
TI-03-V-125	2.0	2.31	0.20	0.98	0.51	8.4	4.5	2.6	17
TI-03-V-126	4.8	1.76	0.30	1.79	0.29	7.3	7.4	3.2	22
TI-03-V-127	4.9	2.19	0.22	1.11	0.46	5.2	3.4	4.3	15
TI-03-V-129	2.5	1.84	0.28	1.09	0.47	1.4	4.2	0.7	19
TI-03-V-130	8.3	2.71	0.15	0.42	0.75	5.3	0.7	0.0	3
TI-03-V-182	4.3	2.55	0.17	0.49	0.71	6.5	2.1	0.6	5
TI-03-V-187	4.0	2.63	0.16	0.56	0.68	6.0	2.7	0.8	9
TI-03-V-188	7.8	2.69	0.15	0.65	0.64	7.9	2.5	2.9	9
TI-03-V-189	9.3	2.46	0.18	0.77	0.59	8.2	3.3	2.1	11
TI-03-V-197	4.0	2.61	0.16	0.51	0.70	6.9	1.1	1.6	5
TI-03-V-202	3.7	2.44	0.18	0.77	0.59	7.6	3.2	1.1	9
TI-03-V-203	3.2	1.34	0.39	1.78	0.29	2.1	7.2	7.2	20
TI-03-V-208	3.2	2.70	0.15	0.44	0.74	6.5	1.2	0.3	5
TI-03-V-216	2.1	1.45	0.36	1.95	0.26	8.3	8.9	6.4	20

Borrow Area A Composite Data

Mean	**2.36**
Mean (mm)	**0.20**
Std Dev (phi)	**0.88**
Std Dev (mm)	**0.54**
% Silt	**6.6**
% Granular	**3.4**
% Gravel	**2.2**
% Shell	**11**

Table E-30 Composite Characteristics for Borrow Area B

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-132	5.4	2.09	0.23	1.16	0.45	4.6	4.0	2.8	16
TI-03-V-205	2.0	2.39	0.19	0.56	0.68	2.2	0.9	0.1	6

Borrow Area B Composite Data

Mean	**2.17**
Mean (mm)	**0.22**
Std Dev (phi)	**0.99**
Std Dev (mm)	**0.50**
% Silt	**4.0**
% Granular	**1.7**
% Gravel	**0.8**
% Shell	**13**

Table E-31 Composite Characteristics for Borrow Area C

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-174	2.3	2.43	0.18	0.53	0.69	2.4	2.5	2.1	9
TI-03-V-178	2.2	2.58	0.17	0.53	0.69	7.0	0.9	4.9	9
TI-03-V-185	4.5	2.54	0.17	0.49	0.71	7.0	1.3	0.9	7
TI-03-V-186	3.3	2.46	0.18	0.44	0.73	3.4	1.2	2.4	7
TI-03-V-192	2.0	2.10	0.23	0.69	0.62	1.5	1.2	0.1	7
TI-03-V-198	3.0	1.84	0.28	1.14	0.45	1.7	4.1	7.1	16
TI-03-V-199	2.2	2.14	0.23	0.70	0.62	1.4	0.7	0.5	7

Borrow Area C Composite Data

Mean	**2.32**
Mean (mm)	**0.20**
Std Dev (phi)	**0.63**
Std Dev (mm)	**0.64**
% Silt	**3.9**
% Granular	**1.7**
% Gravel	**2.6**
% Shell	**9**

Table E-32 Composite Characteristics for Borrow Area D

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-223	3.0	2.00	0.25	0.75	0.59	1.1	2.9	2.8	12
TI-03-V-224	2.0	2.23	0.21	0.54	0.69	1.4	2.1	0.6	7
TI-03-V-228	6.7	2.16	0.22	1.23	0.43	8.2	6.1	2.5	10

Borrow Area D Composite Data

Mean	**2.13**
Mean (mm)	**0.23**
Std Dev (phi)	**0.99**
Std Dev (mm)	**0.50**
% Silt	**5.2**
% Granular	**4.6**
% Gravel	**2.2**
% Shell	**10**

Table E-33 Composite Characteristics for Borrow Area E

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-240	2.8	2.00	0.25	0.82	0.57	2.3	1.4	2.5	7
TI-03-V-241	4.0	2.25	0.21	0.61	0.66	3.9	0.6	0.3	4

Borrow Area E Composite Data

Mean	**2.15**
Mean (mm)	**0.23**
Std Dev (phi)	**0.69**
Std Dev (mm)	**0.62**
% Silt	**3.2**
% Granular	**0.9**
% Gravel	**1.2**
% Shell	**5**

Table E-34 Composite Characteristics for Borrow Area F

Boring Number	Depth (ft)	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
TI-03-V-245	2.5	0.96	0.51	1.64	0.32	1.6	7.2	7.3	18
TI-03-V-369	3.0	1.20	0.44	1.90	0.27	5.6	6.8	9.5	2

Borrow Area E Composite Data

Mean	**1.09**
Mean (mm)	**0.47**
Std Dev (phi)	**1.78**
Std Dev (mm)	**0.29**
% Silt	**3.8**
% Granular	**7.0**
% Gravel	**8.5**
% Shell	**10**

Table E-35 Compatibility of Native and Borrow Sand

Native Beach	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell
Surf City/North Topsail Beach	2.15	0.23	0.71	0.61	1.2	1.1	0.5	9

Borrow Site	Mean (phi)	Mean (mm)	Std Dev (phi)	Std Dev (mm)	% Silt (0.062 mm)	% Granular (2 - 4.76 mm)	% Gravel (4.76 mm)	% Shell	Overfill Ratio	Silt Correction Factor	Final Overfill Ratios Corrected for Silt Content
A ^	2.36	0.20	0.88	0.54	6.6	3.4	2.2	11	1.29	1.07	1.38
B ^	2.17	0.22	0.99	0.50	4.0	1.7	0.8	13	1.18	1.04	1.23
C ^	2.32	0.20	0.63	0.64	3.9	1.7	2.6	9	1.50	1.04	1.56
D ^	2.13	0.23	0.99	0.50	5.2	4.6	2.2	10	1.15	1.06	1.21
E ^	2.15	0.23	0.69	0.62	3.2	0.9	1.2	5	1.02	1.03	1.15
F ^	1.09	0.47	1.78	0.23	3.8	7.0	8.5	10	1.14	1.04	1.19
G	2.05	0.24	0.98	0.51	5.2	2.7	5.2	10	1.11	1.05	1.17
H	2.21	0.22	0.65	0.64	2.6	1.6	2.0	7	1.16	1.03	1.19
J	2.12	0.23	0.75	0.60	4.5	2.3	1.1	10	1.01	1.05	1.15
L	2.05	0.24	0.94	0.52	6.3	2.8	3.1	10	1.09	1.07	1.16
N	1.86	0.28	0.96	0.51	3.6	3.2	4.8	9	1.05	1.04	1.15
O	2.12	0.23	0.86	0.55	6.2	2.0	4.7	9	1.08	1.07	1.15
P	2.01	0.25	0.96	0.52	5.5	2.4	6.6	7	1.09	1.06	1.15
Q	2.30	0.20	0.66	0.63	5.9	2.4	2.3	10	1.37	1.06	1.46
S	1.62	0.32	1.12	0.46	3.3	6.6	4.1	21	1.06	1.03	1.15
T	1.78	0.29	0.95	0.52	2.8	3.0	3.9	17	1.03	1.03	1.15

^ These borrow areas have been identified for the Topsail Beach Federal project. The excess material not used for these projects is planned to be available for the Surf City/North Topsail Beach Federal project. This amount is approximately 9.68 million cubic yards.